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LATE QUATERNARY HISTORY OF THE PARRY PENINSULA TO PERRY RIVER REGION, NORTHWEST TERRITORIES

BY

DANIEL ERNEST KERR ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled LATE QUATERNARY HISTORY OF THE PARRY PENINSULA TO PERRY RIVER REGION, NORTHWEST TERRITORIES submitted by DANIEL ERNEST KERR in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in GEOLOGY.

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April 29 1994

ABSTRACT

The Late Quaternary history of the Parry Peninsula - Perry River area, Northwest Territories is reconstructed from the Quaternary stratigraphy, glacial landforms, past sea levels and marine paleoecology. The stratigraphic record in this isostatically-depressed coastal lowland consists of a well defined succession of seven sedimentary facies: (A1) massive diamicton; (A2) stratified diamicton with sorted sediments; (B) thinly-bedded horizontal and cross-stratified sand and gravel; (C) interlaminated sand, silt and clay; (D) massive silty clay; (E) thinly bedded sand, silt and clay; (F) poorly bedded to massive sand; (G1) large-scale planar cross-stratified sand and gravel; and (G2) horizontal bedded and trough cross-stratified sand and gravel. These facies were deposited in a variety of rapidly changing sedimentary environments, beginning with the retreat of the Laurentide Ice Sheet through to postglacial marine emergence as follows: (A1) till deposited mainly by lodgement from active ice; (A2) glacial diamictons deposited by a combination of debris flows and iceberg rain-out modified by subglacial meltwater processes; (B) subaqueous outwash issuing from subglacial meltwater conduits; (C) glaciomarine rhythmites deposited by sediment-laden underflows, interflows and overflows away from the ice margin; (D) glaciomarine and postglacial marine fine-grained sediments resulting from suspension deposition; (E) sublittoral marine rhythmites influenced by tidal and fluvial processes; (F) littoral deposits representing the last phase of marine regression; and (G1, G2) glaciomarine and marine deltas constructed by glaciofluvial outwash and fluvial sediments during deglaciation and in postglacial times.

Ice retreat has left a relatively orderly and predictable sedimentary succession which is generally consistent over a distance of 1 000 km. Two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (facies A, B, C, D) and a conformably overlying coarsening-upward regressive marine sequence (facies E, F, G). The distribution and lateral extent of each facies falls within a sequence in which ice-proximal facies (diamicton, outwash, rhythmites) shift landward during ice retreat, whereas marine sublittoral and littoral facies (silty clay, sandy rhythmites, sand and gravel) shift seaward during the marine regression.

The Parry Peninsula - Bathurst Inlet region experienced rapid deglaciation in response to marine incursion across isostatically-depressed terrain during high sea level stands. Marine limits, frequently defined by ice-contact deltas, range from 10 m a.s.l. in the west to 225 m a.s.l. in the east and were formed from approximately 12.5 to 9 ka BP respectively. Seven relative sea level curves demonstrate that the mainland coast has shown initial rapid emergence and then progressively less emergence which has been replaced by submergence from Paulatuk to Bernard Harbour during the late Holocene. Regions to the east continue to experience emergence. Sea level curves have shown persistently higher rebound from west to east. The

pattern and magnitude of observed postglacial sea level changes are in accord with theoretical predictions. In areas outside the glacial limit, as well as close to, but within the glacial limit, sea level initially falls during the early and middle Holocene, and then begins to rise due to the migration of the forebulge in late Holocene times. Submergence becomes progressively younger from west to east. Closer to the centre of ice loading, emergence has progressed since deglaciation.

During the period of marine inundation, a rich and diverse marine fauna existed from which paleoecological conditions can be derived. Stable, near-normal marine conditions are associated with the deeper parts of the postglacial sea. Temperatures and salinities were in the range of 0° C and 33-34 ppt respectively. Modern-day faunal equivalents can be found off the coasts of Frobisher Bay, Alaska, Greenland and Norway. Relatively shallow waters are characterized by species different from those in open-marine offshore environments. Only the most tolerant foraminifera, ostracode and bivalve species were able to successfully colonize the climatically severe sublittoral and littoral environments. Brackish-water marginal marine conditions resulted from dilution of nearshore marine waters. Paleotemperatures attained 5° to 10° C in summer, and paleosalinities ranged from 10 to 34 ppt. Postglacial marine deposits exhibit lowest abundance and diversity in nearshore environments, but this increases progressively in deeper-water sediments.

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CHAPTER 1 - INTRODUCTION

The first observations on the glacial geology of the north-central mainland coast of the Northwest Territories were by J.J. O'Neill (1924) during the Canadian Arctic Expedition of 1913-1918. Since this time, glacial geology studies have focussed on large-scale physiographic surveys (Bird, 1955; Blake, 1963; Craig, 1960; Mackay, 1952, 1958). Many of the most recent advances in Quaternary geology were undertaken by or in conjunction with the Geological Survey of Canada. Although some local physiographic effects of glaciation have been refined by Kerr (1989), McMartin and St-Onge (1990), Mercier (1984) and St-Onge and McMartin (1987), the stratigraphy and nature of marine transgression during ice retreat and postglacial emergence have received little attention. All glacial features in the study area are attributed to glaciation by the Laurentide Ice Sheet during the Late Wisconsin.

This study documents the Late Quaternary stratigraphy, sea level history and paleoecology of marine sediments along approximately 1 000 km of coastline from Parry Peninsula, southwestern District of Mackenzie, to the Perry River, at the District of Keewatin western boundary. This area includes regions immediately within the northwestern most limits of the Laurentide Ice Sheet as well as regions closer to the centre of ice loading. The study area was chosen for the following reasons: no attempt had been made to undertake a regional study and synthesis of the Late Quaternary stratigraphic record; limited sea level studies were available in this coastal region (Bird, 1955; Blake, 1963), and this region bridges the mainland glacial record with that of the southwest Arctic islands (Sharpe, 1984, 1988, 1992; Vincent, 1984, 1989). The main objectives of this investigation are: a) to examine for the first time the Late Quaternary coastal stratigraphy of raised glacial and postglacial sediments; b) to interpret environments of deposition based on stratigraphic, sedimentologic, geomorphic and fossil data; c) to reconstruct the Late Wisconsin and Holocene glacial history; and d) to document changes in postglacial sea level. The results of these objectives are presented and discussed in Chapters 2, 3 and 4.

Chapter 2 entails a detailed description and interpretation of seven sedimentary facies relating to glacial and marine sedimentation. Their distribution and associations are presented through regional stratigraphic studies of 20 representative sections. The succession of sedimentary environments throughout and following deglaciation is established.

Chapter 3 documents the history of postglacial sea level changes in seven areas which have experienced significant differential isostatic rebound. Seven provisional sea level curves are

presented and their glacioisostatic implications discussed. The initial pattern of emergence and subsequent submergence, as well as temporal variations of emergence rates are interpreted on a regional basis. The sequence of regional ice-front positions during ice retreat is also presented, based on geomorphological, stratigraphic and radiocarbon data.

Chapter 4 focuses on paleoecological studies of the late-glacial Franklin Sea, an extension of the Arctic Ocean which inundated isostatically depressed coastal lowlands. By examining foraminifers, ostracodes and bivalve molluscs from marine sediments spanning the last 12 000 years, paleoenvironmental conditions are interpreted. Sedimentary environments and paleodepth provide a framework to explain variations in microfossil diversity and abundance.

The main conclusions of Chapters 2, 3 and 4 are summarized in Chapter 5, together with a brief review of potential research topics for future investigations to resolve remaining problems.

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CHAPTER II - LATE QUATERNARY HISTORY OF THE PARRY PENINSULA - PERRY RIVER AREA, N.W.T.[1]

INTRODUCTION

Numerous reconnaissance studies have been undertaken dealing with the glacial history of the Parry Peninsula to Perry River area, Northwest Territories (Fig. II-1), but few have looked at land/sea interactions in these coastal regions. Stratigraphic studies are lacking. The purpose of this paper is to present for the first time the stratigraphy of Late Quaternary deposits exposed in the study area and to relate it to the regional geomorphology. The Quaternary history of this region is poorly known and no detailed stratigraphic investigations have been carried out. This study elucidates the history of marine incursion and subsequent regression, and establishes the succession of depositional environments during deglaciation and in the Holocene. Stratigraphic investigations focus on glacial, glaciofluvial, glaciomarine and marine sediments, deposited over a period extending from the retreat of the Late Wisconsin Laurentide Ice Sheet to the Late Holocene. Regional facies associations are presented in order to show the extent of Late Quaternary deposits and their relationships with one another.

The study area extends 1 000 km along the coast, from 125° to 104° W, and 125 km southward from the coast. Research was undertaken in cooperation with Geological Survey of Canada and I.N.A.C. (NWT Geology Division) who facilitated logistical support. A total of 128 sections were examined, of which 20 are presented in detail. These sites are considered to be representative of the stratigraphic record in their respective locations.

METHODS

Fieldwork was carried out from several base camps over the summers of 1986 to 1989. Rotary-wing and fixed-wing aircraft were used to gain access to most sites. Preliminary interpretation of the surficial geology of the study area was carried out using aerial photographs. Large-scale ice-flow directional features (drumlins, flutings) and glacial landform (moraines, eskers, ice-contact deltas) were plotted on 1:50 000 and 1: 250 000 base maps. Ice-flow directions were also obtained from striation measurements on exposed bedrock and crag-and-tail features. Stratigraphic studies included detailed descriptions of the nature and extent of lithostratigraphic units exposed in coastal sections and river banks. Characteristics described included types of contacts, lateral and vertical extent of units, internal structures and bedding style, texture, as well

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[1] A version of this chapter has been accepted for publication by the Geological Survey of Canada as Bulletin 465 (in press).

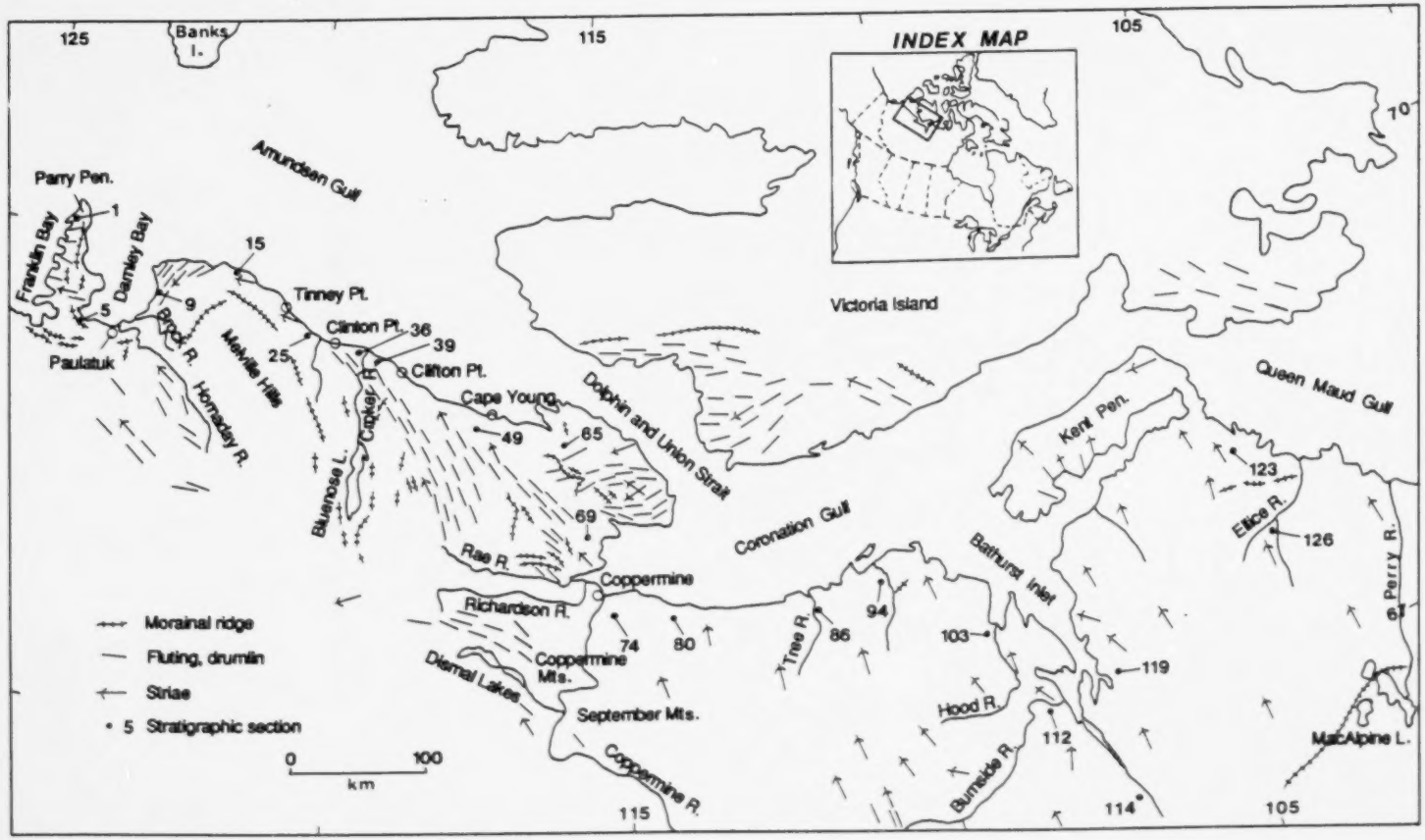

Figure II-1: Location map of the study area, illustrating glacial features and location of selected stratigraphic sections referred to in Figure II-3. Modified in part from Blake (1963), Craig(1960), Kerr (1989), Klassen (1971), Sharpe (1988) and St-Onge and McMartin (1987).

as clast lithologies, shape and size. In places with little or no slumped material on a cliff face, sections were cleared, measured and sampled for grain size and fossil analyses. Samples were carefully chosen so as to be representative of each unit as a whole. Wherever possible, organic matter such as wood, peat, and marine bivalves were collected for radiometric dating. Geographic locations of sections are illustrated in Appendix II-1 (in pocket) and their description by sedimentary facies is summarized in Appendix II-2. Grain size analyses were carried out in the Sedimentology Laboratory of the Geological Survey of Canada, using dry sieving and pipette methods.

BEDROCK GEOLOGY

The bedrock geology in the study area consists of Archean to Cretaceous age rocks. A generalized bedrock map is presented in Figure II-2. To the west, Parry Peninsula is underlain by flat-lying Paleozoic (Upper Cambrian to Lower Ordovician) dolomite, shale, sandstone and gypsum with minor quartz and chert (Yorath *et al.*, 1981). South of Parry Peninsula and east of Darnley Bay, Mesozoic (Lower Cretaceous) rocks consist principally of moderately indurated sandstone, mudstone and coal (Yorath *et al.*, 1969, 1975). Locally, Paleozoic sandstone unconformably overlies Proterozoic dolomite and sandstone from Darnley Bay, east to Tinney Point (Blackadar *et al.*,1960). The present author noted poorly indurated Cretaceous sandstone and siltstone, with coal horizons exposed along the Croker River. Flat-lying Paleozoic carbonates and sandstones occur south of Dolphin and Union Strait (Campbell, 1983), and in the Coppermine area, where they are intercalated with gabbroic sills (Baragar and Donaldson, 1973). South of Coronation Gulf, bedrock consists of sedimentary and volcanic Proterozoic and Archean rocks (Blackadar *et al.*, 1960; Fraser, 1963). Proterozoic greenstone belts and Archean gneiss and granite occur on the west, south and east sides of Bathurst Inlet. To the north, Kent Peninsula is underlain by Archean granite and flat-lying dolomite, limestone and sandstone of Proterozoic age which are locally overlain by Lower Paleozoic dolomite and sandstone. Along the southern shore of Queen Maud Gulf, Archean gneiss and granite are found outcropping over extensive areas.

PHYSIOGRAPHY

The physiography of the coast of the Northwest Territories mainland is highly variable, and reflects in part the events of the last glaciation. In the west, Parry Peninsula (Fig. II-1) has been subdivided into the Parry Plain Peninsula and the Parry Peninsula Moraine (Yorath *et al.*, 1969). Much of Parry Peninsula consist of flat-lying carbonates and sandstones and lies below 30 m a.s.l.

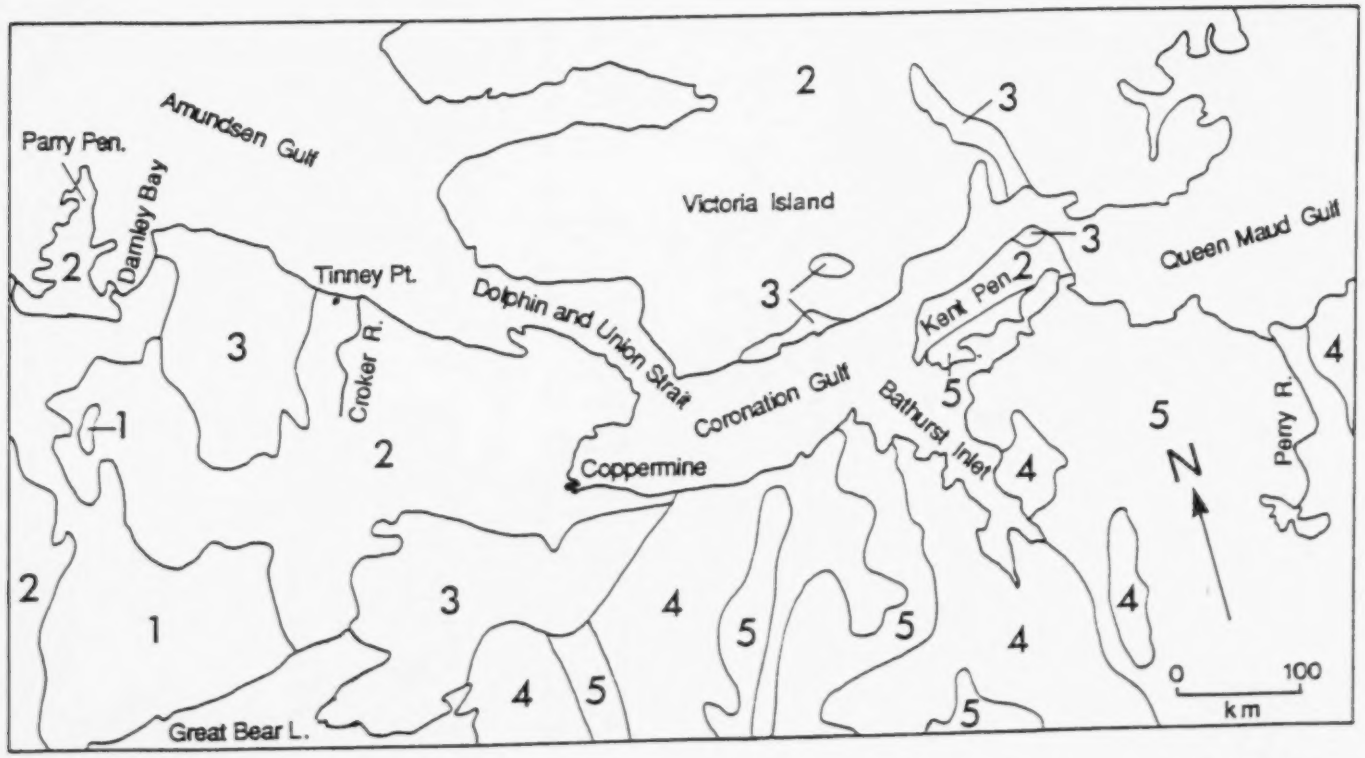

Figure II-2: Simplified bedrock geology map of the study area. 1 - Mesozoic (Cretaceous): shales, sandstone, coal; 2 - Paleozoic (Silurian, Ordovician, Cambrian): carbonates, shales, sandstone; 3 - Proterozoic: carbonates, shale, sandstone; 4 - Proterozoic: greenstone belts, metamorphosed sediments; 5 - Archean: gneiss, granite. Modified after Douglas (1969) and Fraser *et al.*, (1978).

South and east of Darnley Bay, the land rises to form the rocky uplands known as the Melville Hills. They extend inland towards the southeast and decrease gradually in elevation south of Clinton Point. The Rae and Richardson rivers form a broad east-west drainage basin south of the Melville Hills. West and south of this basin, the terrain rises slowly becoming increasingly rocky towards the Coppermine and September Mountains. Along the southern shore of Coronation Gulf west of Bathurst Inlet, a rocky inland plateau of metamorphosed sediments and granite attains 400 m elevation and slopes northward 5 km to 10 km down to the sea. Bathurst Inlet is a 225 km long embayment extending southeast from Coronation Gulf. On both its east and west sides, the land rises steeply to form rugged gneiss and granite hills at elevations of at least 300 m and in some places 600 m. Kent Peninsula, to the northeast of the inlet, is a relatively featureless plain of gently inclined carbonates. Southeast of the peninsula, a broad coastal plain extends to 125 km inland where it reaches 215 m a.s.l. In the vicinity of Ellice River and eastward, most of the region is of low relief, rarely exceeding 60 m a.s.l.

PREVIOUS STUDIES

Knowledge of the glacial geology of the study area and more specifically the last marine episode is limited. Many previous surficial geology studies have focussed on large-scale physiographic surveys (Bird, 1955; Blake, 1963; Craig, 1960; Mackay, 1952, 1958) and more rarely, on detailed surficial mapping or stratigraphy in a few isolated areas (Kerr,1989; McMartin and St-Onge, 1990; Mercier, 1984; and St-Onge and McMartin, 1987). Although the general physiographic effects of glaciation are known, the extent of the marine transgression and mode of emergence have received little attention. No one has attempted a regional study and synthesis of Quaternary stratigraphy, sedimentology and glacial history.

Early explorers of the nineteenth century travelled by ship from the Mackenzie Delta to Kent Peninsula (Franklin, 1828; Richardson, 1851), making notes on the local natural history. It was not until the Canadian Arctic Expedition (1913-18) that general observations were made regarding the Pleistocene deposits along the Arctic coast (O'Neill, 1924). He reported the presence of stony clay on the east side of Darnley Bay, a raised beach at 21 m a.s.l. and gravel terraces at 36 m, 52 m and 61 m a.s.l. south of Paulatuk. Gravel terraces along the Brock River at 30 m, 43 m and 67 m a.s.l., as well as at Clinton Point (91 m a.s.l.) were also noted. Marine shells were found at elevations of 52 m at Clifton Point and 152 m at the mouth of the Tree River. O'Neill (1924) deduced marine emergence of approximately 180 m in the Darnley Bay - Brock River area. The present study, however, suggests a much lower elevation for the marine limit. Mackay (1952) mapped lineations in ground moraine, eskers and major postglacial drainage channels and terraces in the Darnley Bay area. Terraces are attributed to fluvial and lacustrine processes, formed

when drainage was initially southwest towards the Hornaday River, perpendicular to the present drainage. Proglacial lakes were impounded between the Amundsen Gulf lobe (Mackay, 1958) and the Melville Hills to the south. As the ice front retreated, proglacial lakes were lowered successively as evidenced by deltas at progressively lower altitudes. Two such deltas were noted by the present author along the Brock River at 73 m and 98 m a.s.l. Recessional moraines on Parry Peninsula record successive frontal positions of the Amundsen Gulf lobe which flowed around the Melville Hills. These investigations were based on minimal supporting stratigraphic observations and did not include discussions of late-glacial and postglacial marine phases. Major morainal deposits of the Melville Hills and Parry Peninsula were also noted by Yorath *et al.*, (1969, 1975, 1981) during bedrock geology investigations, but descriptions are limited to broad physiographic divisions.

Bird (1955) made preliminary studies of postglacial marine submergence in the Bathurst Inlet area, based on evidence from elevations of marine shells, beaches and washing limits. Emergence deduced from ground moraine, strandlines and molluscs varies from 170 m - 220 m a.s.l. at the mouth of the Inlet, to 196 m - 225 m at the southwest extremity. A series of dominant strandlines between 200 m and 189 m, 65 m and possibly 23 m a.s.l. may be related to periods of temporary halts or slowing down in emergence (Bird, 1955), although emergence has been essentially continuous in postglacial times (ibid). A regional reconnaissance survey from the Hornaday River to the Tree River by Craig (1960) identified a peripheral zone of Laurentide Ice characterized by recessional moraines from Darnley Bay to Coppermine, and a central zone of regular ice-retreat extending into the mainland interior towards the southeast. Based on the distribution of glacial landforms, a summary of the pattern of ice retreat was presented for the Darnley Bay - Coppermine region, although no temporal framework was included. It was postulated that the ice-margin along Coronation Gulf may have been static for a period of time, although no moraines were noted to support this interpretation. Approximate limits of postglacial marine submergence were initially identified at 213 m at the Tree River, decreasing to 146 m east of Coppermine, 91 m west of Cape Young and 45 m near Tinney Point. No raised marine features were reported west of this last site.

A similar reconnaissance investigation was undertaken by Blake (1963) who mapped the regional directions of ice flow and end moraines in the Tree River to Perry River region (Fig. II-1). He presented a review of glacial features, along with a preliminary interpretation of their significance. Evidence of marine submergence is based on beach ridges, wave-cut benches, deltas and changes in nature of drift cover. Blake confirmed that marine limit at the Tree River was 213 m a.s.l., between 213 m - 228 m in Bathurst Inlet and approximately 198 m near MacAlpine Lake further east. Radiocarbon data suggest that the Tree River area was ice-free by 10.2 ka and that ice had retreated to MacAlpine Lake by at least 8.2 ka. Preliminary sea-level studies showed

that recent uplift was slightly lower at the north end of the Inlet than in the southern region. In the Parry Peninsula and northern Melville Hills region, Klassen (1971) produced preliminary surficial geology maps, indicating the limits of Late Wisconsin glaciation. However, no glaciomarine or marine sediments were identified, except for isolated beach ridges along Amundsen Gulf.

More recent studies of glacial history, focussing on glaciolacustrine reconstructions, were carried out by Mercier (1984) in the Richardson and Rae River basin west of Coppermine. The glaciolacustrine to marine transition in this region was described through stratigraphic and sedimentological studies (Kerr, 1987). Vincent (GSC, personal comm., 1988) recognized evidence for marine submergence in the form of raised fossiliferous deposits south of Darnley Bay. South of Coppermine, St-Onge (1987, 1988) mapped and interpreted the surficial deposits of the Coppermine River valley. In the Bluenose Lake region, six morphosedimentary zones were identified (St-Onge and McMartin,1987) on the basis of landform and dominant sediments. Based on geomorphic evidence, deglaciation history of the Bluenose Lake - Coppermine area was discussed by McMartin and St-Onge (1990). However, events were not related to a chronological or stratigraphic framework.

Few detailed stratigraphic and sedimentologic studies of deglacial glaciomarine environments have been undertaken in other regions of the Canadian Arctic. Stewart (1991) presents the first detailed description of a raised marine, ice-contact Arctic fjord environment on Ellesmere Island, focussing on glacial environments and less on postglacial sedimentation. Although the topographic setting differs considerably from those in the Parry Peninsula to Perry River region, striking similarities exist in the physical appearance some of the glaciomarine facies. A notable difference between these two areas however, is the style of glaciation, i.e., a large mid-latitude continental (Laurentide) ice sheet, as opposed to high-latitude, smaller ice caps more local in nature. Similarly, Bednarski (1988) discusses the geomorphic and stratigraphic context of lithofacies associations on northern Ellesmere Island during the last glaciation. Many similarities between his observations and this study are apparent, even though significant differences exist between the two regions in terms of physiography, style of glaciation and deglaciation, sea level history and size of the study areas.

SURFICIAL GEOLOGY

The surficial geology consists principally of till, glaciofluvial outwash, glaciolacustrine sediments, as well as glaciomarine and marine deposits. Till veneers and blankets, forming hummocky moraine cover much of the northern and central regions of Parry Peninsula (Klassen, 1971), as well as the Darnley Bay coastlands. The Melville Hills are surrounded by exposed rock with discontinuous till veneers and blankets. The coastal lowlands south of Coronation and

Queen Maud gulfs, and the more elevated uplands further inland consist of extensive bedrock outcrops with widespread till veneers and isolated pockets of till blankets. North-south end moraines (Fig. II-1) are common on Parry Peninsula. Moraine ridges form concentric rings to the northwest, north and northeast of the Melville Hills. A series of moraines also occurs between Bluenose Lake and Dolphin and Union Strait (Craig, 1960). Large drumlin fields oriented northeast-southwest curve around the Melville Hills. To the southeast, they join a second large drumlin field south of Clifton Point through to Coppermine. Kames, eskers and outwash plains are common throughout the study area and are frequently associated with washed till and bedrock.

Isolated glaciolacustrine sediments occur from the Melville Hills to Coppermine, and south of Coronation Gulf. They are common in the Rae and Richardson River basins, as well as the Coppermine River valley (St-Onge, 1988). A series of perched deltas defines marine limit which increases in elevation from west to east. South of Amundsen and Coronation gulfs, the coastal plains below marine limit consist largely of discontinuous fine-grained glaciomarine and marine sediments of variable thickness. Similar conditions exist around Bathurst Inlet where veneers of marine sand and silty clay mantle the terrain, except for the tops of bedrock hills. Flights of raised marine beaches a few tens of metres above sea level are a common in small bays. They become less abundant further inland, where they are frequently associated with the flanks of eskers.

SEDIMENTARY FACIES

Sedimentary units identified in stratigraphic sections have been subdivided into facies based on lithology and structure (Walker, 1984). The location of 20 of these sections is shown in Figure II-1. The stratigraphic data were projected onto a base line oriented east-west as seen in Figure II-3 (in pocket). Seven sedimentary facies have been identified, representing a range of depositional environments. Their characteristic properties are summarized in Table II-1.

FACIES A: DIAMICTON

Facies A, diamicton, is subdivided into two subfacies: massive, pinkish grey diamicton (subfacies A1), and stratified brownish grey diamicton interbedded with sand (subfacies A2).

Subfacies A1: massive diamicton

Description

Subfacies A1 has a silty-sand matrix and is matrix-supported (photo unavailable). It is generally less than 3 m thick, but varies from 1 m to 15 m, and forms distinct structureless beds.

Table II-1: Sedimentary characteristics of facies A to G

Facies or subfacies	Thickness (m)	Grain size (%)*				Matrix texture**	Munsell colour	Sedimentary structures	Type of stratification
		G	S	Si	C				
A1	1.0-15	24	48	35	17	silty sand	7.5YR 7/2	rare oriented clasts	massive
A2	0.5-30	25	48	41	11	silty sand	10YR 6/2	rare normal grading; boulder pavements	poorly to well stratified; cross-laminations
B	0.2-25	1	82	6	12	sand	10YR 6/2	rare dropstones	massive or planar and trough cross-beds
C	0.5-30	0	17	47	36	clayey silt	7.5YR 7/2	dropstones	planar and cross-laminated
D	1.0-20	0	1	33	66	silty clay	7.5YR 6/2	mottled; rare lenses	massive
E	0.5-20	0	43	40	17	silty sand	10YR 5/2	load structures; bioturbation	laminated to thinly bedded
F	1.0-4.0	1	71	17	12	silty sand	10YR 5/3	convolutions	massive to poorly stratified
G1	2.0-35	-	-	-	-	sand	10YR 6/2	rare normal grading	large-scale planar cross-beds
G2	0.7-4	-	-	-	-	sand	10YR 6/2	scour and fill	large-scale horizontal bedding and trough cross-beds

*G-gravel, % of whole sample
S-sand, Si-silt, C-clay, % of < 2mm fraction
**After Shepard (1954)

Clasts are angular to well-rounded, and cobbles and boulders are commonly striated and faceted; lithology varies with local bedrock. Angular slabs of dolomite, siltstone and sandstone accompanied by minor granite, gneiss and gabbro are predominant in the west part of the study area whereas granite, gneiss, siltstone and sandstone are generally more common in the east. Diamicton is compact with no preferred fabric but a few isolated cobbles aligned parallel to ice flow were observed locally. Lower contacts with bedrock are either sharp or gradational in which the shattered bedrock grades upward into clast-rich diamicton. The upper contacts of this subfacies are sharp and planar to irregular. Diamicton beds are relatively uniform in texture, and weathered surfaces do not appear to differ in colour or texture from fresh exposures. This subfacies is found throughout the study area (Fig. II-3), and is restricted to the base of sections when overlain by other facies.

Interpretation

Subfacies A1 is interpreted as lodgement till, deposited by actively flowing ice (Dreimanis, 1988). The massive, compact nature of this matrix-supported diamicton, abundance of striated clasts as well as angular, local lithologies suggest basal deposition (cf. Eyles *et al.*, 1983). The absence of stratified horizons (Boulton,1972) indicates a lack of running water during basal melting. The process of lodgement tends to plaster faceted clasts or frozen aggregates on to the subglacial floor during pressure melting (Boulton, 1976; Shaw, 1982). The textural characteristics of subfacies A1 observed in stratigraphic sections of surficial diamicton that are fluted or drumlinized may also suggest this diamicton is a subglacial basal till.

Subfacies A2: stratified diamicton with sorted sediments

Description

Subfacies A2 consists of diamicton beds with sand-rich horizons. This matrix-supported diamicton has a silty sand matrix and contains clasts ranging from pebbles to boulders up to 2.5 m in diameter (Plate II-1). As in subfacies A1, it incorporates a wide variety of rock types, from angular clasts of fragmented bedrock to well rounded clasts of variable composition, some of which are striated. Although not as compact as subfacies A1, subfacies A2 diamicton often exhibits weak internal stratification and rarely normal grading. Subfacies A2 varies from 0.5 m to 30 m thick. These sediments are found near the base of some sections (Fig. II-3) and locally are interbedded with deposits of facies B and C. Individual diamicton beds are variable in texture and average 1 m in thickness but range from 0.15 m to 4 m. Poorly sorted sediments consist of thin beds of silt, sand and pebbles, less than 10 cm thick, as well as discontinuous lenses 1-2 m long. These are

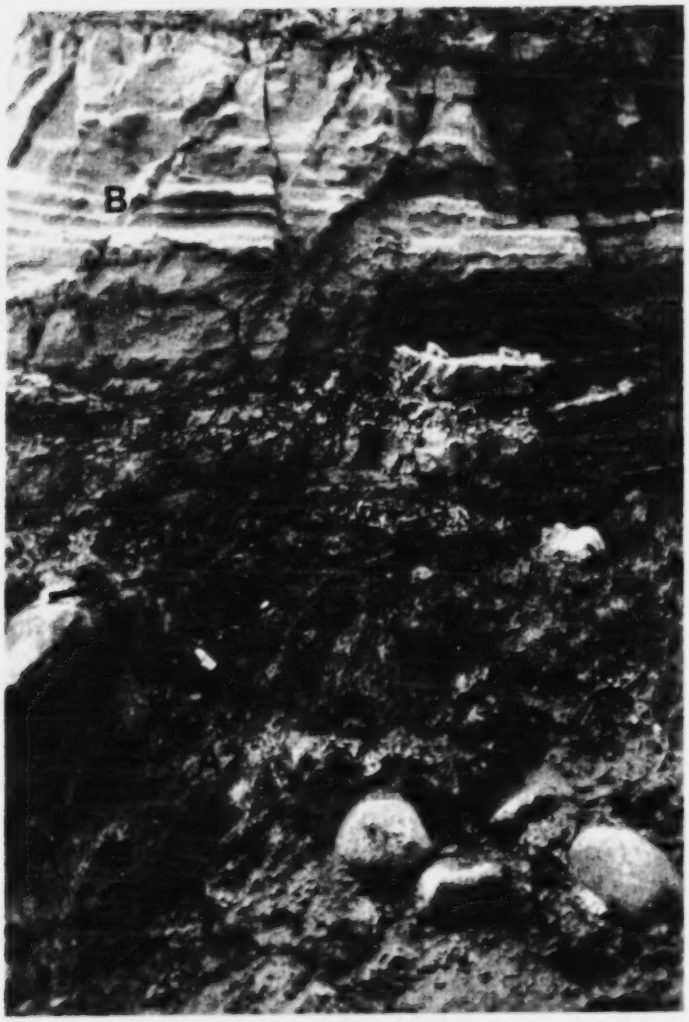

Plate II-1: Poorly bedded diamicton of subfacies A2 sharply overlain by horizontal stratified sand of facies B. Cobbles are about 15 cm in diameter (section 103).

found within and between diamicton beds and are sometimes associated with boulder pavements. Locally, small clasts depress underlying strata and are overlain by draped laminations. Upper and lower boundaries between diamictons and sand-rich horizons may be sharp or gradational. Subfacies A2 occurs throughout the study area, but is not volumetrically significant.

Interpretation

Subfacies A2 occurs within the coastal belt of marine submergence which was established during deglaciation. It underlies and is interbedded with other facies deposited in glaciomarine environments. Several sedimentary processes are attributed to the deposition of subfacies A2. Matrix-supported, ungraded diamictons with erosive contacts and little or no stratification are interpreted as glacially-derived debris flows (Middleton and Hampton, 1976) with chaotic fabric that moved along the sea bottom, and whose sediment source was derived from the glacier base as indicated by the predominance of a single, locally derived lithology. In other cases, ripple marks, dropstone structures and more diverse clast lithologies in diamictons of subfacies A2 suggest that they not only the product of sediment gravity-flow processes, but a combination of subglacial meltwater sedimentation and possibly ice-rafting. The release of debris aggregates by overturning icebergs produce diamictons that may undergo reworking by bottom traction currents originating from subglacial meltwater (Domack *et al.*, 1985). Such meltwater currents are believed to be responsible for sand and gravel lenses and layers associated with diamicton beds of this facies. These ice-proximal currents induced local erosion as evidenced by small cut-and-fill structures. Gravel lags observed in numerous sections may have resulted from preferential removal of finer fractions or may have been produced directly from high in-flow discharge carrying coarse material. Stewart (1991) reported similar diamictons (his lithofacies association LA I) from the base of glaciomarine sequences on northern Ellesmere Island.

FACIES B: SMALL-SCALE HORIZONTAL AND CROSS-STRATIFIED SAND AND GRAVEL

Description

This facies consists of stratified fine to coarse sand to pebbly gravel with minor amounts of silt and clay. It is generally light brownish grey in colour and is found throughout the region. Beds vary in thickness from 0.5 m to 25 m. This facies is most commonly underlain by subfacies A1 and A2 and overlain by facies C (Fig. II-3). Sedimentary structures associated with this facies include tabular and trough cross-beds composed of medium to coarse sand with clasts up to 15 cm in diameter, horizontally stratified to structureless fine to coarse sand beds, and lenses of silty clay to

coarse sandy gravel. This facies also exhibits ripple-drift cross-laminations, sinusoidal ripple laminations and planar laminations; a typical sequence consists of type A grading into type B climbing ripples (Jopling and Walker, 1968), overlain by draped undulating laminae which may in turn grade up into or be truncated by horizontally laminated sands. Type B ripples, with high angles of climb, may also grade up into type A ripples, with lower angles of climb (Plate II-2). Beds are generally from 0.1 to 1.5 m thick, exhibiting both sharp and gradational upper and lower boundaries. Paleocurrent directions are variable, but generally indicate deposition from currents flowing in a westerly to northerly direction (paleoseaward).

Interpretation

In a regional context, facies B occurs below the limit of marine submergence and is interpreted to be subaqueous outwash (Rust and Romanelli, 1975). This interpretation is supported in part by the position of facies B within a stratigraphic sequence (underlain by coarse glacial diamictons and overlain by fine-grained glaciomarine rhythmites) which suggests that these sediments were deposited in a proglacial environment at an ice-sea interface. Planar and cross-stratified sand and gravel were deposited by subglacial meltwater discharges, released as efflux jets (Eyles and Eyles, 1992; Powell, 1990), and deposited in tunnels, or at the ice margin, into standing water. Deposits of this type are characteristic of glaciofluvial (eskerine) environments where deposition at the mouth of ice tunnels results in a subaqueous fan (Anderson and Ashley, 1991; Boothroyd, 1984; Domack, 1984; Dowdeswell and Scourse, 1990; Harrison, 1975; Powell, 1981; Powell and Molnia, 1989; Rust and Romanelli, 1975; Saunderson, 1975; Smith and Ashley, 1985; Stewart, 1991). The resulting sedimentary succession consists of small-scale planar tabular cross-beds resulting from bedform that migrated across the fan surface. Coarser meltwater sediments are deposited near the mouth of subglacial tunnels by seaward-moving turbulent jets as the competency of these flows decreases away from the mouth (Mode *et al.*, 1983). Massive coarse sands are deposited from suspension which is caused by turbulent discharge at the point of exit. Further downflow, flat-bedded and cross-laminated sand and silt are transported by traction and rapid sediment fall-out from decelerating unidirectional flow away from the ice front. Gently sloping submarine fan surfaces permit density underflows to transport large amounts of fine to coarse grained sediment during the summer melt season, as described by Leckie and McCann (1982) and Powell (1981).

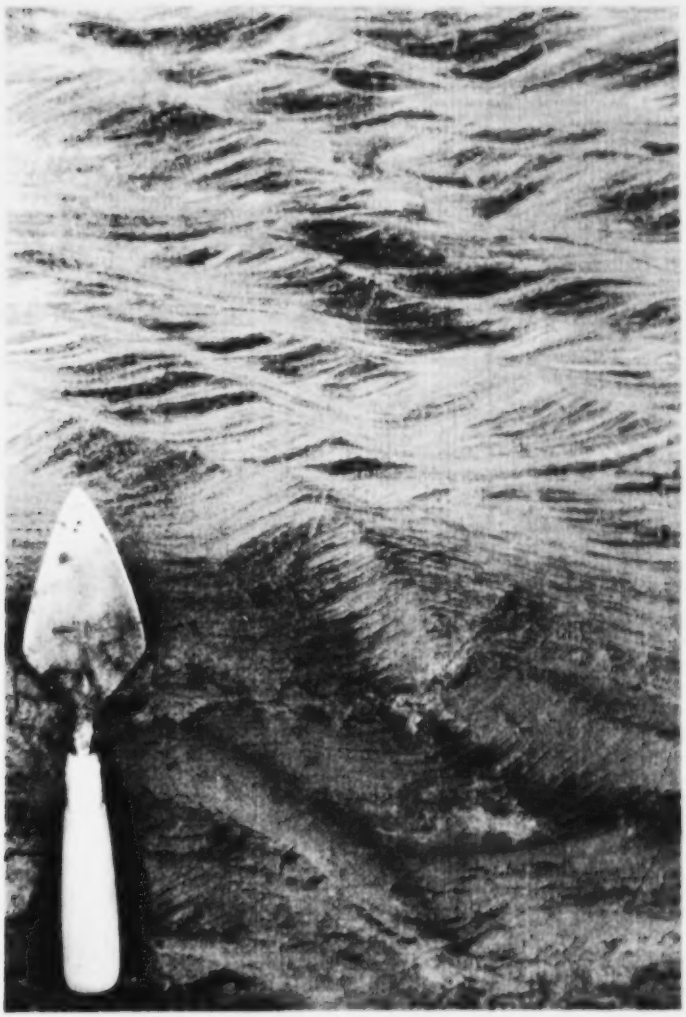

Plate II-2: Cross-laminated sands of facies B in which type B climbing ripples grade upward into type A ripples. Trowel measures 25 cm, (section 2).

FACIES C: INTERLAMINATED SAND, SILT AND CLAY

Description

The diagnostic characteristic of facies C is thinly bedded to laminated, sand, silt and clay rhythmites. This facies is found throughout the study area, occurring most commonly above facies B (Fig. II-3) or more rarely overlying subfacies A1 or A2. Fine sand, silt and clay horizons, 0.1 to 1.5 cm thick, have either sharp or gradational upper and lower contacts (Plate II-3). Each rhythmite is defined by cyclic changes in colour and texture giving rise to striking, repetitive interbeds. Where rhythmites gradationally overlie the coarser sand deposits of facies B, beds may attain thicknesses of 10 to 50 cm and consist of graded fine sand to silty clay with internal sand or clay laminae, 0.1 to 1 cm thick. These thicker basal rhythmites may in places exhibit thin sequences of type A and B climbing ripples. Beds may exhibit intraformational soft-sediment deformation structures such as convolute bedding and diapir and flame structures. Diamicton pods and striated clasts up to 30 cm in diameter also occur. The latter depress underlying strata, occasionally truncating them, and are overlain by draped laminations. Beds of facies C, overlying sandy deposits of facies B, become progressively thinner and finer grained towards the top of sections but those overlying subfacies A1 and A2 show no obvious trends. In addition, laminations do not appear to thin or thicken laterally over a distance of up to 20 m. Where this facies overlies subfacies A1, lower contacts are sharp, whereas lower gradational boundaries occur over subfacies A2. The thickness of units comprised entirely of facies C ranges from as little as 0.5 m to 24.5 m. The upper contact of facies C with facies D (Fig. II-3) is a gradational one. In this upper zone, the rhythmic character becomes indistinct, and the poorly laminated silt and clay grade up into massive mud of facies D. Facies C is locally fossiliferous, containing marine foraminifera and bivalves.

Interpretation

Deposits of facies C are interpreted as glaciomarine sediments resulting from meltwater stream discharging in subglacial and ice-marginal environments forming underflows, interflows and overflows of suspended sediments. Numerous studies on cyclic or interlaminated sand and mud units have shown that similar deposits characterize glaciomarine sedimentation (Domack, 1984; Domack and Lawson, 1985; Dowdeswell and Scourse, 1990; Drewry *et al.*, 1981; Elverhoi *et al.*, 1983; Eyles and McCabe, 1989; Gilbert, 1982; Mackiewicz *et al.*, 1984; Orheim *et al.*, 1981; Powell, 1981; Stevens, 1985; Stewart, 1988, 1991).

Subglacial meltwater stream may introduce large amounts of sand and gravel into the marine environment. If the discharge of subglacial meltwater stream has a sufficiently high

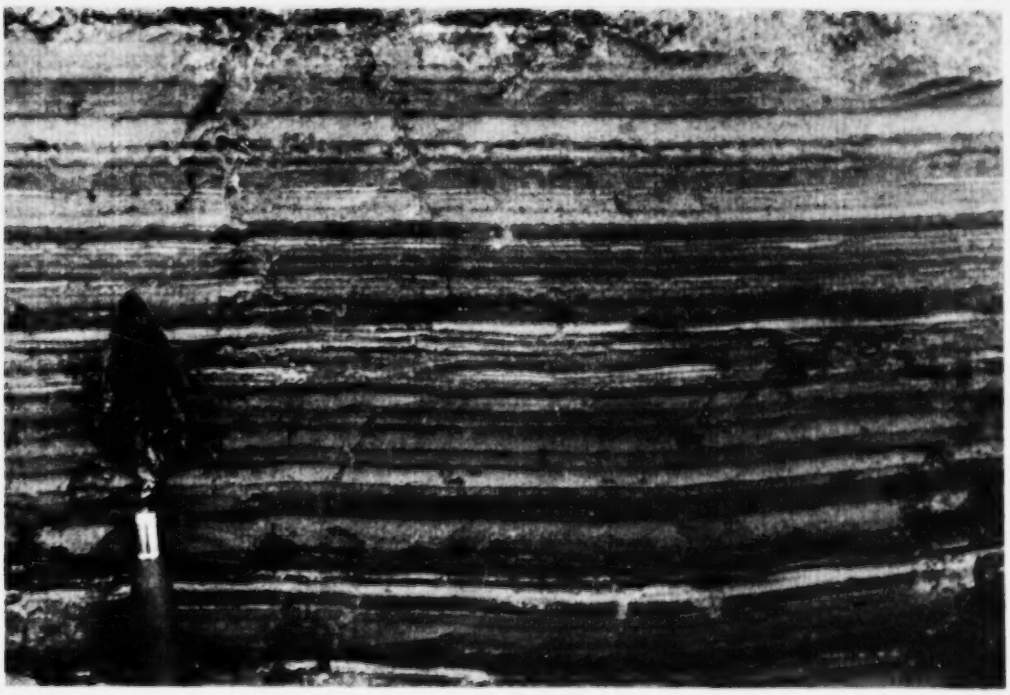

Plate II-3: Interlaminated sand (white), silt (medium grey) and clay (dark grey) rhythmites of facies C (section 112).

sediment load, flow occurs along the sea floor forming an underflow. These underflows transport sand, silt and clay away from the ice front, leaving only the coarser sediments near it. The nature of the underflows may be that of high concentration turbidity currents (Middleton, 1966), because laminae are poorly sorted and individual laminae are not always graded. Thick laminae and thin beds of sand are formed as the coarse grained sediment is deposited in a proximal environment; current ripples and erosional contacts suggest traction currents which are more common closer to the ice front. Although subglacial system may have greater suspended sediment concentrations than within supraglacial or englacial flows (Hammer and Smith, 1983), underflows are difficult to generate because abnormally high suspended sediment concentrations are required (~40 g/L) in order to overcome the buoyancy effects of sea water (Gilbert, 1979, 1982; Mackiewicz *et al.*, 1984).

If subglacial meltwater discharge has a moderate to low sediment concentration, it may be buoyed-up because of density differences between it and the marine water column, into which it may spread laterally forming an interflow or an overflow. Coarse grained sediment is dropped out of suspension from the turbid plumes more quickly than fine grained sediment, resulting in a higher sand content in the proximal environment; suspended sediment begins to settle as the meltwater spreads out and current velocities decrease. Consequently, the interlaminated sand, silt and clay of facies C would imply fluctuating conditions where bottom current sediments alternate with relatively slow settling of suspended silty and clay. A sharp boundary between laminae reflects a sudden change in depositional process, whereas the gradational nature of a contact is interpreted as transitional shift of sedimentary conditions. Changes in the depositional environment can be brought upon by fluctuations in meltwater velocity, duration of flow, and sediment concentrations which is consistent with observations made by Arnborg (1955), Boothroyd and Ashley (1975), Cohen (1979), and Pickrill and Irwin (1983) regarding glaciofluvial system. Facies C is similar in appearance to proximal cyclopsams and distal cyclopels (Mackiewicz *et al.*, 1984; Cowan and Powell,1990), as well as Stewart's (1991) lithofacies association IV and V.

A proximal to distal relationship, due to the retreat of the ice, is inferred by the fining upward trend towards the stratigraphic top of facies C in term of the thickness of laminae and their textural composition, as finely laminated silt and clay dominate distal sediment deposition. Sediment settling from turbid surface plumes is probably the main source of fine grained glaciomarine deposits (Syvitski and Murray, 1981; Gilbert, 1982). This interpretation is suggested by the lack of bottom current structures in sediments of facies C, the fine grain size and relatively poor sorting which is indicative of deposition in quiet water primarily by settling from suspension.

Isolated striated clasts are locally present within the fine grained rhythmites of facies C. As they are too large to have been transported by traction currents, they are believed to be dropstones. Ice-rafted debris may melt out individually or may be dumped by the turning over of

an iceberg or floe producing debris lenses (Anderson *et al.*, 1980; Keys and William, 1984; Ovenshine, 1970). The irregular masses of diamicton occasionally interbedded with rhythmites suggest that these materials represent ice-rafted sediment. A rainout origin (Eyles *et al.*, 1983) is further indicated by the downfolded and draped nature of the laminate sediments surrounding the clasts (Thomas and Connell, 1985).

The soft sediment deformation structures associated with this facies are believed to have been formed in response to differential downward pressure exerted by the weight of overlying sediment (vertical loading). Compaction and dewatering of oversaturated sediments results in diapirs and mass movement down very gentle slopes between horizontally bedded deposits (Banerjee and McDonald, 1975; Lowe, 1975; Rust, 1977).

FACIES D: MASSIVE SILT AND CLAY

Description

Facies D consists of mottled pinkish grey silty clay which is for the most part massive (photo unavailable); rare thin silt or fine sand stringers and small gravelly lenses are restricted to the lower part of this facies. Facies D, by volume, is the most significant sedimentary unit within the study area. It is found all along the coast, varying in thickness from 1.5 m to commonly 20-25 m (Fig. II-3). Upper contacts are gradational to sharp with facies E and G1; lower boundaries are gradational with facies C, but sharp and planar to irregular with facies A1, A2 and B. This unit, like facies C, is fossiliferous and contains several species of marine ostracodes, foraminifera and bivalves.

Interpretation

Facies D is interpreted as a marine deposit resulting from suspension in quiet water environments of the most distal glaciomarine settings, as well as in the relatively deep waters of the open marine conditions which existed following deglaciation. The rare occurrence of sandy gravel lenses and sand partings at the base of facies D in some sections (sections 86, 94, Fig. II-3) are thought to be debris originating from icebergs which may have persisted longer and drifted further out to sea than most. The mixing of meltwater stream and the rivers draining deglaciated coastal regions is characterized by flocculation of suspended clay sediment leading to the formation of floccules which settle together to form massive silt deposits (Kranck, 1981). It is believed that facies D is the product of flocculation and agglomeration of silts and clays as its fine texture, lack of current structures and its stratigraphic position indicate deposition in a standing

water body of marine origin. Radiocarbon dates on marine shells found in these sediments indicate that silty clay was accumulating throughout the Holocene. Paleoenvironmental interpretations based on rich and diverse foraminiferal, ostracode and bivalve assemblages suggest bottom-water temperatures of approximately 0°C and salinities of 33-34 ppt for these deep-water sediments. Modern-day faunal counterparts have been reported in relatively deep waters of Frobisher Bay and in coastal waters of Greenland, Alaska and Norway.

FACIES E: THINLY BEDDED SAND, SILT AND CLAY

Description

Facies E consists of interbedded sediments composed of sand, silt and clay; individual strata range from 1 mm to 15 cm in thickness. The cyclic variations in grain size and colour of each horizon define the rhythmic nature of this deposit. Strata have gradational and sharp upper and lower contacts and may be either massive or show internal stratification. Locally, these rhythmites grade up vertically into lenticular, undulatory and more rarely, flaser bedding; asymmetrical current ripples associated with the undulatory or wavy bedding are overlain by bifurcated-wavy flaser bedding, which are in turn succeeded by thinly interlayered sand, silt and clay. The sediments of facies E are particularly rich in organic plant debris (twigs, leaves, rootlets), as well as *in situ* marine macro and microfauna. Bioturbation, in the form of burrows, and soft-sediment deformation structures are also generally common throughout the facies (Plate II-4). Facies E varies in thickness from 0.5 m to 20 m, although average thicknesses are in the range of 5-10 m (Fig. II-3). The lower boundary of this facies is gradational with facies D, as is the upper contact with facies F. Where facies E occurs as the uppermost stratigraphic unit in sections, cryogenic and pedogenic alteration have destroyed most of its primary sedimentary characteristics.

Interpretation

The rhythmic nature of facies E, its stratigraphic position and fossil content, all suggest a shallow water marine environment in which bedding resulted in part from variations in sedimentation due to variable cycles of fluvial discharge in response to short-term climatic changes. Rivers draining the coastal regions are responsible for the introduction of terrestrial plant fragments into the marine environment. Deposits similar to these described by Hillaire-Marcel (1979) are characteristic of shallow, isolated marginal marine basins in which they often complete a regressive marine sequence. The sedimentary structures encountered in facies E may also suggest tidal influences. They ressemble lenticular, wavy and flaser bedded sequences overlying

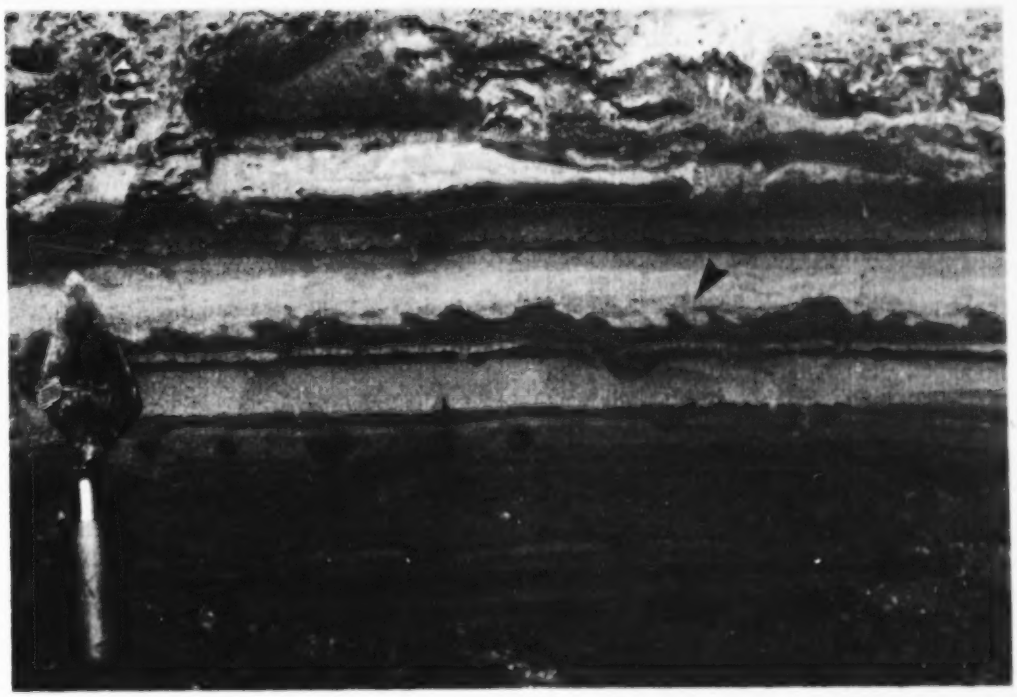

Plate II-4: Flame structures (arrow) and oxidation aureoles surrounding organic debris within the silty sand rhythmites of facies E, section 118.

the rhythmites which are characteristically found in tidal environments (Dalrymple, 1992; Reineck and Singh, 1980). Lenticular and wavy structures are formed where alternating periods of moving and slack water occur as in tidally influenced regimes or where the process of sediment supply is rhythmic or periodic (Leeder, 1982; Terwindt, 1981). Flaser bedding results from the alternation of bedload transport and suspension settlement during slack water periods, which may also give rise to complex varieties of tidal bedding (Klein, 1977). Comparable rhythmic deposits described by Domack (1984) also have a tidal origin, as do those described by Clifton (1983) and Smith *et al.*, (1990) from tidal marine and glaciomarine environments with tidal ranges of 2 m to 7 m. In the present study, it is difficult to determine the degree tidal influence on marine sedimentation as the tidal range around Coppermine is only 0.17 m (Institute of Ocean Sciences, 1983). Under these conditions, tidal processes are not as active as in meso- and macro-tidal environments.

Load and flame structures, as well as involutions associated with the rhythmites of facies E are evidence of post-depositional deformation. Dewatering and differential loading are responsible for flame structures. The shallower waters of the postglacial sea are characterized by foraminiferal, ostracode and bivalve assemblages which are distinct from those associated with the deeper, more open-marine offshore environment of facies D. The fauna associated with facies E represent only the most tolerant shallow-water species capable of successfully colonizing this seasonally rigorous environment. Paleotemperatures attained 5-10°C in summer, whereas paleosalinities were in the range of 10 to 34 ppt, depending on climatic seasonal conditions.

FACIES F: POORLY BEDDED TO MASSIVE SAND

Description

Deposits of Facies F consist of a brown silty sand which is structureless to crudely bedded (photo unavailable). Locally, these sands contain horizons of coarse sand to pebbles which may on occasion form planar cross-bedded strata (section 39, Figure II-3), where pebbly sands compose the 10 -15 cm thick strata which dip 10° towards 205°. Facies F consistently overlies facies D and E, where its lower boundaries are gradational, and is found at the top of many sections (Fig. II-3). These deposits are fossiliferous, containing both marine bivalves and foraminifera and may exhibit convolute bedding where stratification is evident.

Interpretation

The stratigraphic position of facies F and its surface expression as raised marine beaches indicate a shallow water to littoral origin. Facies F, however, lacks the high degree of sorting which

is representative of a constant energy level over a long period in the littoral environment (Folk, 1980). The poorly sorted nature of facies F is attributed to: (1) Arctic shorelines are affected by wave action for only 6 months or less each year and often undergo reworking by sea ice during much of this time (Jefferies, 1977), and (2) the ability of waves to effectively sort sediments is inhibited by protective layers of snow and ice on beach surfaces (Hume and Schalk, 1964; Greene, 1970) in early fall.

Only rarely is planar cross-stratification observed. Where present, it is interpreted to be a beach whose landward slope facies is preserved. Longshore bars typically consist of cross-bedding dipping landward and seaward (Davidson-Arnott and Greenwood, 1976). It is possible that high wave energy during a short period was involved in its formation.

More typically, facies F consists of planar laminated and poorly bedded silty sand, which contrasts with the trough and tabular crossbedding and cross-laminations associated with other nearshore settings (Clifton *et al.*, 1971; Howard and Reineck, 1981). A reason for these differences could be that a low-energy environment existed at the time of deposition and as discussed above, wave action may have been limited. Paleoenvironmental conditions similar to those associated with facies E are indicated by marine bivalves and foraminifera.

FACIES G: LARGE-SCALE HORIZONTAL AND CROSS-STRATIFIED SAND AND GRAVEL

Facies G, large-scale horizontal and cross-stratified sand and gravel, is subdivided into two subfacies: large-scale planar cross-bedded sand and gravel (subfacies G1), and horizontal bedded and trough cross-bedded sand and gravel (subfacies G2).

Subfacies G1: large-scale cross-stratified sand and gravel

Description

Sediments of facies G1 consist primarily of coarse sand and granules, as well as pebbles and cobbles, although the latter may entirely dominate certain deltas near marine limit. Large-scale planar crossbedding is the dominant structure in which internal bedding varies from 10 cm to 30 cm in thickness and sometimes shows fining upward cycles. Angles of dip range from 7° to 32° and upper and lower boundaries are sharp. Occasionally, at the base of this sequence are finer-grained sediments, with lower angles of dip of 2° to 5°. Facies G1 is unconformably overlain by facies G2, and varies in thickness from 2 m to 32 m (Plate II-5). Paleocurrents associated with the cross-stratification vary from section to section but suggest flow directions towards 275° through to 360° and 090°.

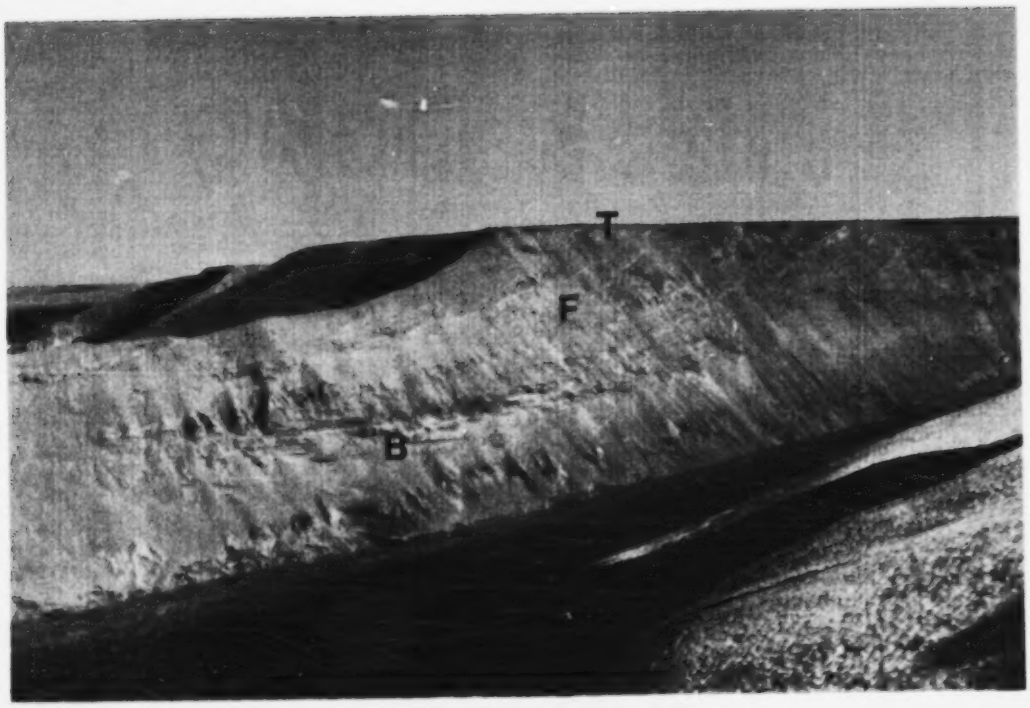

Plate II-5: Perched marine delta showing thin topset beds (T), steeply inclined foresets (F) dipping towards N.N.E., and lower bottomset beds (B); total thickness 34 m; view is to the southeast (section 28).

Interpretation

Facies G has been interpreted as a deltaic complex on the basis of its sedimentary characteristics and the morphology of its surficial sediments. Most marine deltas in the study area have their apex to the south and extend northward in a lobate form with an arcuate front. This form is typical of coarse deltas, as opposed to digitate forms which tend to be comprised of finer sediments (Miall, 1984; Selley, 1970). The structures associated with facies G are typical of Gilbert type deltas (Shaw, 1977). Facies G1 is interpreted as foreset bedding in the middle to lower portions of deltas, with poorly exposed bottomset beds at its base. It consists predominantly of subparallel beds of sand and gravel, showing dips commonly 20° to 30°. The coarse nature of the sediment in foresets and the absence of ripples suggest the rapid deposition of a large amount of sediment. Many deltas exhibit ice-collapse structures and were formed in contact with ice and fed by meltwater streams. Comparable Holocene glaciomarine deltas have been described by Stewart (1991) on Ellesmere Island.

Subfacies G2: large-scale horizontal and trough cross-stratified sand and gravel

Description

Subfacies G2 consists of medium to coarse sand which may locally contain abundant pebbles and cobbles. Planar bedded sand and gravel 0.1 m to 1 m thick are common, and lenses of sand to gravel as well as trough crossbedding infilled by planar laminations of medium to coarse sand are also present. Marine bivalves occur in some sections, occasionally in life position, but more commonly as single valves. Facies G2 is found in isolated areas overlying facies G1 (Fig. II-3) and varies in thickness from 0.7 m to 4 m. Paleocurrent directions are variable, ranging from northwestward to northeastward.

Interpretation

The sediments of facies G2, consisting of crudely planar beds with occasional trough cross-bedding or scour and channel-fill structures, are believed to be topset deposits of fluvial origin representing braided streams (Rust, 1978). This interpretation is supported by braided paleochannels preserved on the surface of deltas. The contact between topset and foreset beds is often erosional and corresponds to the youngest sea level into which the delta was built (Gustavson *et al.*, 1975). Postglacial deltas in the study area have braided streams with large bedloads common during spring melt in Arctic environments where precipitation is erratic and vegetation sparse (Cohen, 1979; Miall, 1984). The distribution of the sediments in the deltaic

environment is the result of a decrease in current velocity as sediment-laden fluvial waters enter a standing body of water (Coleman and Prior, 1981). This process is responsible for the coarsening upward sequence resulting from the progradation of the delta.

FACIES ASSOCIATIONS

As noted by Karrow (1984), individual facies are sometimes difficult to interpret when considered alone, but the recognition of facies associations and vertical sequences is a useful analytical tool. It is therefore helpful to define specific associations which group together different sedimentary facies that are environmentally or genetically related. Any preferred vertical position of a facies may also have an important bearing on the interpretation of a sequence (Shaw, 1975; Walker, 1984). In addition, sequences of deposition are established on the basis of sediment distribution, frequency and thickness of each facies.

In this study, four different facies associations have been identified from sedimentary successions:

1. Subfacies A1 and A2: massive and stratified glacial diamictons.
2. Facies B and C: stratified glaciofluvial clayey silt and sand and gravel.
3. Facies D, E and F: massive to stratified marine sand, silt and clay.
4. Subfacies G1 and G2: large-scale horizontal and cross-stratified sand and gravel.

The first two are the direct result of deglaciation processes. During the retreat of the Laurentide Ice Sheet, marine waters were in contact with the ice front, inundating the isostatically depressed coastal lowlands. Tills and meltwater sediments were deposited along the ice margin in subglacial and glaciomarine environments. The third and fourth are the product of the marine regression resulting from postglacial uplift. This period is characterized by a coarsening-upward off-lap sequence. Bednarski (1988) described broad glaciomarine facies successions and their geomorphology from northern Ellesmere Island, comparable to the facies associations listed above. The following provides a detailed description of the characteristics for individual facies as they relate to facies associations 1 to 4.

The oldest surficial deposits in the region are the tills and glacial diamictons of subfacies A1 and A2[2]. The association between subfacies A1 and A2 is suggested by their lithological similarities and stratigraphic characteristics. These subfacies may occur together (Fig. II-3, section 25) or individually. Subfacies A1 commonly lies directly on bedrock and is generally confined to the western regions of the study area (sections 9, 15, 25, 39). Subfacies A2 is more widespread,

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[2] Unconsolidated deposits predating the last glaciation have been observed along the Croker River, but their exact age is unknown (St-Onge and McMartin, 1987; Kerr, unpublished data).

occurring along the coast near or at the base of sections 25, 49, 80, 103, 123, 126. Subfacies A2 is not considered to be laterally extensive. It occurs at elevations from 1 to 2 m (section 123) to 163 m (section 80) in stratigraphic sections, but may be found up to at least 220 m a.s.l. as a surficial deposit. Subfacies A1 and A2 may be abruptly overlain by facies D (sections 9 and 49), or more commonly succeeded by facies B and C respectively (sections 25, 80, 103 and 126).

A second facies association is expressed in several sections (25, 36, 69, 80, 103, 112 and 126) where facies B appears to grade up into facies C. Facies B is believed to have a subaqueous glaciofluvial origin, because it overlies subfacies A1 and A2, and is closely related to the laminated sediments of facies C. The latter is interpreted as the product of subglacial and englacial meltwater stream entering a proglacial setting. Consequently, these deposits may be found overlying glacial diamictons and underlying the most distal glaciomarine and postglacial marine silty clays. Cheel and Rust (1982) and Stewart (1991) described a similar vertical succession of sediments from a retreating ice front, comprising a fining-upward sequence, with gravelly sands at the base and increasingly distal fine-grained sediment at higher stratigraphic levels. Thus facies B and C are associated with proximal positions close to an ice margin which are transitional between glaciofluvial and glaciomarine environments. Each of these facies associations can be related to changes in sedimentary processes which are a function of distance from the ice front; this can best be explained by a series of depositional processes which may generate a number of different facies in the downcurrent direction. Lateral gradations between facies B and C were not observed, but have been reported elsewhere (Stewart, 1991). Similar transitions between sedimentary structures associated with these two facies have been described by Smith and Ashley (1985) in glaciolacustrine environments.

The subaqueous outwash deposits of facies B may occur as thin, isolated occurrences which makes it impossible to trace them laterally. Thicker sequences (sections 15, 36, 69, 112) are indicative of proximal, ice-marginal environments where more sediment was available. Their proximity to kames and eskers suggests a close depositional association with these features. In the central to eastern part of the study area, there is an overlap of the two most volumetrically significant sedimentary facies, the marine deposits of facies D and the glaciomarine rhythmites of facies C. Facies C attains its greatest thickness in the Bathurst Inlet region (sections 94, 103, 112 and 114). Thinner sequences of facies C occur further east (sections 123 and 126), as well as in the west (sections 25, 36 and 39). Facies C in sections 69 and 80 appears more isolated because of its relatively high elevation, although facies C occurs as high as 190 m down to 1-2 m a.s.l.

The third sedimentary relationship is that of facies D, E and F which conformably overlie facies C. Facies D, E and F form a coarsening-upward cycle in which silty clay grades upward into stratified sand, silt and clay, through to massive and stratified silty sand. These three facies occur in a variety of gradational sequences, although one or more of the three facies within this

sedimentary association may be absent at any one locality (sections 9, 39, 49 and 114). Where facies D is directly overlain by facies F, it is believed that fluvial and tidal influences were minimal.

The dominant sedimentary unit in the central and eastern regions is facies D which can be found in sections 25 to 65, 74 to 103, and 114 to 126. These silty clays reflect a marine environment which persisted throughout the Holocene. Noticeable regional variations in thickness of this facies have been observed in the lowlands along the coast. In general, maximum thickness in the west is 2-3 m, whereas it increases eastwards to 15-20 m. The greatest accumulations were recorded in sections along rivers draining broad, shallow depressions which extend 100 km or more inland. Stony and shelly lag deposits atop certain sections suggest the removal of some unknown amount of surficial material.

Facies E forms part of a common coarsening upward sequence in many sections. It is frequently associated with present-day bays which likely existed in the past as protected, paleogeographic marine embayments into which rivers drained. Such environments occurred along the coast, but only in restricted areas which are often separated by significant distances from one another (sections 1, 65, 74, 86, 119 and 123).

Facies F represents the last stage of marine deposition. The interpretation of facies F as a littoral deposit explains its common surface occurrence as raised beaches, as well as its stratigraphic position above facies E and/or D, which are associated with progressively deeper water environments. Facies F also overlies facies A-C at higher elevations which did not experience prolonged marine submergence and at lower elevations where it has eroded into these facies. These littoral sediments are rare above 150 m a.s.l. and are most commonly observed in sections below 75 m a.s.l. In most localities however, they occur as surficial deposits (sections 1, 9, 74 and 86) of limited extent. This facies is absent from many sections as it is the most susceptible to erosion due to its stratigraphic position.

The last facies association relates to subfacies G1 and G2 consisting of foreset and topset beds respectively (section 5). These deltaic deposits are isolated in their distribution and are predominantly found at or near marine limit from 225 m to 10 m a.s.l. They may also occur below marine limit along major rivers as a series of perched deltas which decrease in elevation towards sea level. Subfacies G1 is dominant and G2 may be poorly developped to absent.

DISCUSSION OF SEDIMENTARY ENVIRONMENTS

The relative thickness and stratigraphic position of facies along a regional transect perpendicular to the coastline records ice retreat and subsequent marine transgression and regression (Fig. II-4). The rate of emergence and the position of sea level are important factors in controlling the nature of depositional environments. Ice retreat resulted in a deglacial sedimentary

succession of relatively consistent thickness, in which facies A, B, C and D shift landward. In the regressive marine sequence, facies G, F, E and D shift seaward from marine limit. The thickness of these facies depended principally upon the duration of submergence. Facies C, D, E and F become thinner towards marine limit and are not present above this level. On a more local scale, the position of ice fronts and subglacial meltwater tunnels were the dominant controls on glaciomarine deposition.

Glaciomarine facies successions in a high Arctic fjord/inlet setting have been described by Bednarski (1988). His model, however, does not distinguish between marine and glaciomarine fine-grained sediments which in the present study have very distinct sedimentary characteristics. A significant difference between Fig. II-4 and the model from Ellesmere Island is a geographic reversal in thickness of marine sediments. The latter incorporates the greatest concentration of postglacial marine sediments immediately below marine limit. These sediments become progressively thinner towards present sea level. The opposite occurs in Fig. II-4 where marine sediments increase in thickness from marine limit to the outer coast. These differences may be explained by a relatively stable sea level near marine limit on parts of Ellesmere Island, allowing for continuous sedimentation. In contrast, the rapid initial emergence following the establishment of marine limit on the mainland coast, permitted only a relatively short period of sedimentation.

Throughout all phases of deglaciation, ice-meltwater-sea interactions played an important role in the deposition of glacial, glaciofluvial and glaciomarine sediments. Subfacies A1 may have been deposited subglacially at this time or perhaps during the initial advance of the ice sheet. Basal debris is released as subglacial till under the glacier and is then covered by debris melted out from the floating terminus or remobilized till by slumping or flows. The stratified diamictons of subfacies A2 exhibit a greater contribution of sediments from underflows and meltwater plumes; upper and lower boundaries of these diamictons are often interbedded with stratified sands, recording episodic traction currents.

When ice retreat is rapid, an acceleration of flow takes place because of rapid steepening in longitudinal gradient (Powell, 1983). As noted by Borns and Matsch (1988), Bednarski (1988) and this study, ice which terminates on land contributes significantly to the marine environment by generation of glaciofluvial system which drain to the sea, often forming deltas at marine limit. The presence of certain geomorphic features in the study area suggest stationary periods and readvances of ice margins due to increased drawdown. Moraines of variable dimensions are preserved along the coast and record ice-contact marine deposition at the margins of the ice sheet. Similar features have been described by Powell (1981) and Eyles *et al.*, (1989) as morainal banks: individual ridges to arcuate belts of hummocky topography marking the former positions of ice sheet margins. During winter months when calving ceases, the ice front may remain stationary

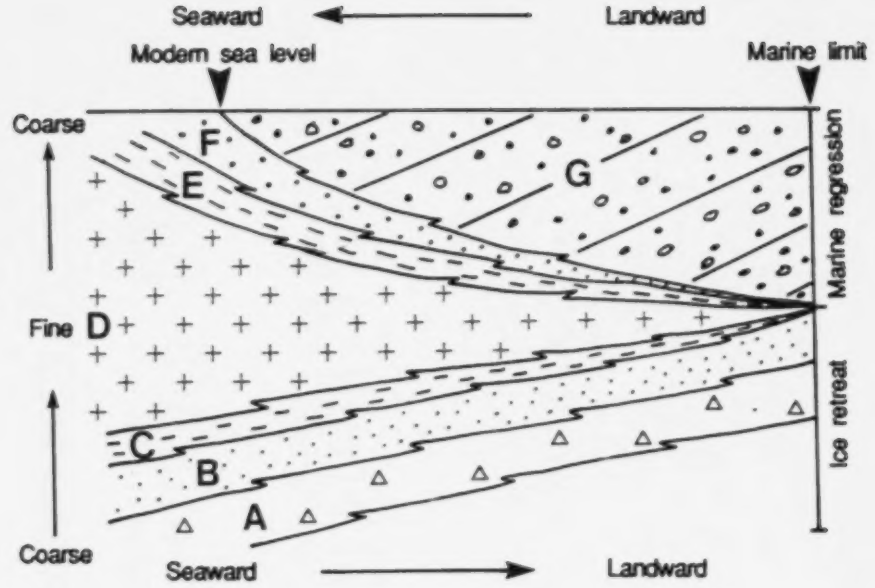

Figure II-4: Schematic time-distance diagram illustrating a composite cross-section of relative thickness and position of facies with respect to sea level. Curved facies boundaries during marine regression phase reflect increased rates of emergence in early postglacial times. In the lower half, facies A to D advance landward up to the marine limit during ice retreat. In the upper half, facies D to G shift seaward during emergence.

or advance tens of metres (Elverhoi *et al.*, 1983). These slight readvances of the ice margin can produce moraines, as can an ice front which slows during its retreat (Mode *et al.*, 1983; Powell, 1983). DeGeer moraines (Plate II-6) have also been observed south of Dolphin and Union Strait, Coronation Gulf and Queen Maud Gulf.

Meltwater produced by temperate glaciers is the predominant transporting mechanism for delivering sediments to the glaciomarine environment. Subglacial meltwater stream contribute coarse-grained material that builds subaqueous outwash fans in ice-marginal environments (Stewart, 1988, 1991). These consist of structureless, planar bedded and cross-stratified sand and gravel strata (facies B) which may accumulate at or beyond the ice front. Occasionally, ice-rafted debris may be incorporated between periods of traction currents and rain-out from suspension. Subaqueous fans in the study area, however, are isolated and were generally short-lived because of the dynamic nature of the ice front, and the change in location of subglacial stream discharge from one meltwater season to the next, as well as variations in flow direction within a single discharge pulse.

Relatively thick sequences of facies C suggest that sedimentation of these glaciomarine rhythmites may have been rapid. The interlaminated characteristics and locally draping nature of the laminae suggest periods when sedimentation was dominated by fall-out from suspension of fine-grained material. These periods were interrupted by intervals of flows and pulses of subglacial, englacial and supraglacial meltwater. Current-rippled sand layers and fine sand partings represent bottom-water traction currents possibly generated by density underflows. The upward decrease in pebbles and sand, and the lack of dropstones record the retreat of the ice margin. The character of the uppermost zone of facies C indicates that ice rafted debris contributed in decreasing amounts from ice-proximal to ice-distal areas. The laminated sediments of facies C may grade vertically and horizontally into the massive marine silty clay of facies D which was deposited beyond the ice front. This transition records progressively more distal conditions as the ice margin retreated; comparable facies are reported from modern and past tidewater settings in Alaska, Spitsbergen and the Canadian high Arctic (Elverhoi, 1984; Mackiewicz *et al.*, 1984; Powell, 1983; Stewart, 1991). Following the retreat of the ice sheet, the deposition of facies D dominated in the offshore environments of the postglacial sea.

Ice-contact glaciomarine deltas define a progressively higher and younger marine limit towards the east, from approximately 10 m a.s.l. in the northern half of Parry Peninsula to 225 m a.s.l. in southern Bathurst Inlet (Plate II-7). Following the establishment of marine limit during deglaciation, a significant decrease in delta building occurred. Few truly marine deltas were constructed in postglacial time, save those associated with the larger rivers draining into the sea. Bednarski (1986, 1988) noted that this was also the case in fjord environments during

Plate II-6: DeGeer moraine 50 m in length, once buried by postglacial marine sediments and now exposed due to erosion; view is to the north in the Kenarctic River valley.

Plate II-7: Perched glaciomarine delta at 221 m a.s.l. (1) and marine deltas at 200 m a.s.l. (2) and 177 m a.s.l. (3), near the mouth of the Burnside River valley; view is to the south.

deglaciation of ice caps on northern Ellesmere Island. This suggests that, for both continental ice sheets and smaller ice caps, the greatest concentration of sediments were deposited early in the glaciomarine phase over a short period of time, and that sedimentation was significantly reduced following this initial influx of sediment. Although sedimentation during deglaciation at any one site is related to the proximity of the former ice, it is the duration of submergence and the proximity to sediment sources that primarily controlled sedimentation during the Holocene. Only in coastal embayments with important fluvial input were marine sediments of facies D permitted to accumulate to significant thicknesses. In protected bays where large amounts of freshwater entered the marine environment, sublittoral and littoral rhythmites (facies E) were deposited. Coarser debris formed the littoral deposits such as beaches, capping the fines and completing a coarsening upward off-lap marine sequence.

Throughout the marine regression, marine action led to wave washing of the progressively emerging landscape, as occurs along the present-day coastline (Plate II-8). Rapid postglacial emergence exposed the sediments to extensive subaerial erosion, giving rise to locally extensive gullying and the formation of badland topography, notably in areas characterized by thick accumulations of glaciomarine and marine silt and clay.

SUMMARY AND CONCLUSIONS

Stratigraphic sequences along the mainland coast record a well defined succession of distinct sedimentary facies which, for the most part, have been reported from other Arctic regions. Beginning with the retreat of the Laurentide Ice Sheet, these facies resulted from a wide variety of rapidly changing environmental conditions. Massive till, produced mainly by lodgement of glacial debris by active ice, was initially deposited on bedrock. Stratified glacial diamictons, often overlying lodgement till, resulted from a combination of debris flows and iceberg rain-out modified by subglacial meltwater processes near the ice front during ice retreat.

Subaqueous outwash deposits issuing from subglacial conduits form a facies sequence which may show several variations. Cross-bedded sand and gravel, massive sand, and planar to cross-laminated fine sand and silt are deposited near the mouth of the ice tunnel. The transition to interlaminated, sand, silt and clay represents a progressive decrease in current velocity in the downstream direction. Sedimentation dominated by sediment-laden underflows, interflows and overflows both near the ice margin and at a distance, led to the deposition of glaciomarine rhythmites. Beyond the influence of the ice sheet and following deglaciation, massive silty clay

Plate II-8: Drumlin field south of Queen Maud Gulf in which drumlins have been reworked into raised beaches as a result of coastal emergence; drumlins display increasing degrees of modification by wave action with decreasing elevation; view is to the northeast.

was deposited in the open marine environment. As the sea regressed to lower elevations due to crustal rebound, sublittoral, littoral and deltaic deposits completed the sedimentary succession.

Ice retreat has left a well-defined, conformable sedimentary succession which is similar over a distance of 1 000 km. The distribution and lateral extent of facies fall within a sequence in which ice-proximal facies (A, B, C, D) would be expected to shift landward during ice retreat, whereas marine sublittoral and littoral facies (E, F, G) would shift basinward during the marine regression. Two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (diamicton, outwash, rhythmites) and a conformable overlying coarsening-upward regressive marine sequence (silty clay, sandy rhythmites, sand and gravel).

Important similarities exist between these facies (A to G) resulting from deglaciation of a continental ice sheet over a wide variety of topographic settings, and sediments deposited by the retreat of relatively smaller tidewater glaciers in the fjords of Alaska and northern Ellesmere Island for example. This suggests that comparable sedimentary processes have occurred in both high-latitude subpolar glaciers and mid-latitude temperate glaciers, and have produced similar sedimentary successions where ice has retreated upgradient. A significant difference between the mainland coast and regions of the high Arctic is the dominance of facies D and to a lesser degree facies E in the marine record throughout the Holocene, and their apparent absence and/or poor representation in fjord settings of northern regions. These massive, offshore silty clay and overlying sublittoral rhythmites are characteristic of the marine offlap sequence throughout the study area.

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Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
1	5	0.0-0.5		cliff top dunes
		0.5-1.5	F	
		1.5-5.0	E	
2	27.5	0.0-13.5	B	paleocurrent towards 205°, 315°
3	30.5	0.0-12.0	B	paleocurrent towards 345°-045° rare coal fragments
4	9	0.0-9.0	E	abundant organic detritus
5	9.5	0.0-1.0	G2	
		1.0-7.0	G1	palaeocurrent towards 335°
		7.0-9.5	D	
6	26	0.0-2.0	G2	
		2.0-26.0	G1	paleocurrents towards 060°, 065° rare coal fragments
7	6	0.0-6.0	F	paleocurrent towards 065°
8	30.5	0.0-3.0	G2	
		3.0-12.0	G1	paleocurrent towards 345°
		12.0-15.0	A1	
9	6.5	0.0-1.0	F	
		1.0-3.0	D	fossiliferous
		3.0-5.5	A1	
		5.5-6.5		dolomite
10	12	0.0-3.0	D	fossiliferous
		3.0-5.0	A1	
		5.0-12.0		shale
11	6	0.0-0.5	D	
		0.5-3.5	A1	
		3.6-6		covered
12	15	0.0-4.0	E	
		4.0-11.0	D	
		11.0-15.0		covered
13	15	0.0-8.0	G1	paleocurrent towards 270°
14	31.6	0.0-5.0	C	
		5.0-6.0	B	paleocurrent towards 345°
		6.0-7.0		covered
15	16.5	0.0-3.5	B	fossiliferous
		3.5-5.0	A1	
		5.0-8.0		dolomite
16	28	0.0-8.0		covered

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
		8.0-18.0	C	
		18.0-26.0	B	paleocurrent towards 020°-060°
		26.0-28.0		covered
17	24	0.0-12.0	E	fossiliferous
		12.0-18.0	D	
18	21	0.0-6.0	F	
19	25	0.0-20.0	A1	
		20.0-23.0		dolomite
		23.0-25.0		covered
20	24	0.0-6.0	A2	
		6.0-8.0	A1	
21	15	0.0-13.0	A1	surface fossiliferous
22	45	0.0-8.0	A1	
23	25	0.0-6.0	D	surface fossiliferous
24	15	0.0-2.0	F	fossiliferous
		2.0-6.0		covered
25	30	0.0-2.5	D	fossiliferous
		2.5-4.0	C	
		4.0-5.0	B	paleocurrent towards 325°
		5.0-9.5	A2	
		9.5-15	A1	
26	46	0.0-4.0	G1	paleocurrent towards 220°, 035°
		4.0-7.5	B	
		7.5-17.5	A1	
27	30	0.0-7.5	F	
		7.5-20.0	C	
		20.0-24.0	B	
		24.0-26.0	A2	
		26.0-28.0	B	
		28.0-29.0	A2	
		29.0-31.0	B	
		31.0-32.0	A2	
28	46	0.0-2.0	G2	
		2.0-32.0	G1	paleocurrent towards 025°-080°
29	39	0.0-30.0	A2	fossiliferous
30	43	0.0-3.0	F	
		3.0-7.0	E	
		7.0-11.0	D	
		11.0-30.0	A2	

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
31	61	0.0-2.0	G2	
		2.0-8.0	G1	paleocurrent towards 005°
		8.0-15.0	A2	
		15.0-30.0	A1	
32	45	0.0-13.0	G1	paleocurrent towards 000°-020°
		13.0-19.0	D	
33	30	0.0-5.0	C	
		5.0-9.0	B	paleocurrent towards 010°
34	61	0.0-9.0	B	paleocurrent towards 240°-340°
35	61	0.0-2.0	D	
		2.0-5.5	C	
		5.5-13.0	B	paleocurrent towards 230°, 250°
36	61	0.0-1.5	D	
		1.5-2.0	C	
		2.0-13.0	B	paleocurrent towards 320°-010° soft sediment deformation
37	52	0.0-2.0	D	fossiliferous
		2.0-10.0	C	
38	46	0.0-3.5	D	fossiliferous
		3.5-4.0	B	
		4.0-6.0	A1	
39	30	0.0-2.0	F	fossiliferous, paleocurrent towards 205°
		2.0-4.0	D	fossiliferous
		4.0-5.0	C	
		5.0-6.5	A1	
		6.5-8.0		dolomite, striae 310°
40	15	0.0-4.5	F	
41	14	0.0-1.0	F	
		1.0-4.2	E	fossiliferous
42	53	0.0-12.0	C	
		12.0-15.0	B	
		15.0-16.0	A1	
43	53	0.0-5.0	C	
		5.0-8.5	B	
		8.5-9.0	A1	
		9.0-12.0		dolomite, striae 330°
44	75	0.0-5.0	E	
		5.0-27.0	C	
		27.0-28.0	B	
		28.0-29.0	A1	
		29.0-30.0		dolomite

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
45	61	0.0-12.0	C	
		12.0-12.5	B	
		12.5-13.0	A1	
		13.0-17.0		dolomite, striae 330°
46	69	0.0-22.0	C	
		22.0-28.0	B	
		28.0-29.0	A1	
47	91	0.0-12.0	G1	paleocurrent towards 348°
48	107	0.0-1.0	G2	
		1.0-17.0	G1	paleocurrent towards 000°-035°
49	76	0.0-4.0	F	fossiliferous
		4.0-8.0	D	
		8.0-14.0	A2	paleocurrent towards 039°, 050°
		14.0-15.0		dolomite, striae 310°, 340°
50	30	0.0-4.0	E	fossiliferous
		4.0-6.0	D	
51	90	0.0-10.0	G1	paleocurrent towards 030°
		10.0-17.0	B	
		17.0-19.0	C	
		19.0-21.0	B	
52	75	0.0-1.0	F	
		1.0-11.0	D	fossiliferous
53	75	0.0-1.0	F	
		1.0-11.0	D	
		11.0-12.0	A1	
		12.0-13.0		dolomite, striae 310°, 332°
54	110	0.0-2.0	F	
		2.0-11.0	C	
		11.0-20.0	B	rip-up clasts
				paleocurrent towards 275°, 295°
55	100	0.0-14.0	C	
		14.0-16.0	B	
56	90	0.0-19.0	C	
57	105	0.0-1.0	F	
		1.0-16.0	C	paleocurrent towards 315°
		16.0-21.0	B	
58	110	0.0-5.0	G1	paleocurrent towards 190°-335°
		5.0-12.0	C	paleocurrent towards 195°
59	100	0.0-15.0	C	

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
60	110	0.0-5.0	D	
		5.0-12.0	C	
61	125	0.0-2.0	A2	
		2.0-12.0	B	paleocurrent towards 090°-115°
62	118	0.0-10.5	B	paleocurrent towards 292°, 330°
63	115	0.0-1.0	D	
		1.0-5.0	C	
		5.0-8.0	B	paleocurrent towards 125°-140°
64	137	0.0-11.0	B	paleocurrent towards 200°-330°
65	27	0.0-3.0	F	cryoturbated
		3.0-6.0	E	
		6.0-12.0	D	
66	27	0.0-2.0	F	
		2.0-12.0	D	
67	18	0.0-3.0		cliff top dunes
		3.0-7.0	F	fossiliferous
		7.0-17.0	E	fossiliferous
68	152	0.0-4.0	G2	
		4.0-19.0	G1	paleocurrent towards 015°-035°
		19.0-22.0	D	
69	125	0.0-5.0	C	fossiliferous paleocurrent towards 264°
		5.0-10.0	B	paleocurrent towards 222°-358°
70	116	0.0-2.0		cliff top dunes
		2.0-8.0	C	paleocurrent towards 048°
		8.0-16.0	B	paleocurrent towards 070°, 075°
		16.0-20.0		covered
71	45	0.0-10.0	D	
72	21	0.0-13.0	D	
73	30	0.0-10.0	B	
74	40	0.0-2.0	F	
		2.0-4.0	E	organic detritus
		4.0-24.0	D	fossiliferous
75	20	0.0-5.0	G	paleocurrent towards 090° fossiliferous
		5.0-13.0	D	fossiliferous
76	140	0.0-1.0	G2	

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
		1.0-9.5	G1	paleocurrent towards 250°
		9.5-12.0	A1	
		12.0-14.0		sandstone
77	140	0.0-35.0	G1	
78	100	0.0-3.0	D	
		3.0-25.0	C	fossiliferous
79	110	0.0-6.0	B	fossiliferous
80	183	0.0-7.5	G1	paleocurrent towards 310°-320°
				fossiliferous
		7.5-9.5	D	fossiliferous
		9.5-15.0	C	
		15.0-18.0	B	
		18.0-19.5	A2	
		19.5-22.0		bedrock, striae 350°
81	152	0.0-1.0	G2	
		1.0-5.0	G1	paleocurrent towards 310°-360°
				fossiliferous
		5.0-7.0	D	fossiliferous
		7.0-32.0	C	fossiliferous
82	177	0.0-3.5	D	fossiliferous
83	137	0.0-5.0	D	fossiliferous
84	91	0.0-10.0	A2	
		10.0-12.0		granite
85	55	0.0-10.5	D	fossiliferous
86	46	0.0-3.0	F	
		3.0-7.0	E	fossiliferous
		7.0-23.0	D	fossiliferous, sandy lenses
87	30	0.0-12.0	E	abundant organic detritus
88	23	0.0-9.0	G1	paleocurrent towards 340°
89	30	0.0-0.7	G2	
		0.7-12.0	G1	paleocurrent towards 000°
90	31	0.0-1.0	F	
		1.0-7.0	E	organic detritus, fossiliferous
91	91	0.0-5.0	D	fossiliferous
92	225	0.0-17.5	G1	paleocurrent towards 320°-010°
93	30	0.0-2.5	G1	paleocurrent towards 010°

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
		2.5-7.0	E	
		7.0-22.5	D	
94	61	0.0-15.0	D	
		15.0-22.5	C	dropstones
		22.5-23.0	A2	
		23.0-25.0		granite, striae 310°
95	30	0.0-2.0	G1	paleocurrent towards 285°-005°
		2.0-8.0	E	organic detritus
		8.0-21.0	D	fossiliferous
96	145	0.0-30.0	C	
97	122	0.0-1.5	G2	
		1.5-23.0	G1	paleocurrent towards 310°-330°
		23.0-38.0	D	fossiliferous
		38.0-40.0	A1	
98	152	0.0-14.0	G1	paleocurrent towards 020°
99	205	0.0-7.0	D	
100	210	0.0-11.0	G1	
101	210	0.0-12.0	G1	
102	198	0.0-1.7	G2	
		1.7-8.0	G1	paleocurrent towards 010°-020°
		8.0-18.0	C	
		18.0-20.0	B	paleocurrent towards 060°-090°
		20.0-22.0		granite, striae 345°
103	34	0.0-10.0	D	fossiliferous
		10.0-14.5	C	dropstones
		14.5-15.5	B	paleocurrent towards 005°
		15.5-20.0	A2	
104	35	0.0-5.0		cliff top dunes
		5.0-15.5	E	paleocurrent towards 300°-340°
				organic detritus
		15.5-31.0	D	
		31.0-34.0	C	
105	61	0.0-9.0	E	
		9.0-27.5	C	fossiliferous, dropstones
		27.5-34.0	A1	
106	91	0.0-4.0	A2	
		4.0-16.0	C	
		16.0-23.0	A2	
		23.0-26.0		siltstone, striae 355°

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
107	152	0.0-10.0	F	
		10.0-23.0	C	fossiliferous, dropstones
		23.0-31.0	A2	
		31.0-34.0		siltstone
108	183	0.0-1.0	G2	paleocurrent towards 020°
		1.0-8.0	G1	paleocurrent towards 275°-010°
		8.0-17.0	C	fossiliferous, sand lenses
		17.0-19.0	A2	
		19.0-24.0	A1	
109	171	0.0-2.0	A2	
		2.0-27.5	B	paleocurrent towards 355°-070° dropstones
		27.5-30.0	A2	
110	182	0.0-15.0	C	
		15.0-22.0	B	
		22.0-31.0	A2	paleocurrent towards 065°
111	91	0.0-14.0	C	fossiliferous
		14.0-16.0	B	
		16.0-38.0	A1	
		38.0-42.0		covered
112	58	0.0-24.0	C	soft sediment deformation dropstones, fossiliferous
		24.0-29.5	B	paleocurrent towards 300°
		29.5-32.0		siltstone, striae 320°
113	33	0.0-3.5		cliff top dunes
		3.5-7.0	F	
		7.0-27.0	E	fossiliferous
114	70	0.0-6.0	F	
		6.0-10.0	D	
		10.0-17.0	C	
		17.0-22.0	A1	
115	30	0.0-3.0	G2	
		3.0-15.0	G1	paleocurrent towards 310°-320° organic detritus
116	9	0.0-9.0	E	fossiliferous, organic deritus
117	67	0.0-6.0	F	
		6.0-8.0	D	
		8.0-12.0	C	fossiliferous
		12.0-19.0	A1	
118	18	0.0-7.0	E	organic detritus, soft sediment deformation

Appendix II-2. Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
119	24	0.0-5.0	F	
		5.0-9.0	E	
		9.0-13.0	D	fossiliferous, dropstones
		13.0-15.0	B	paleocurrent towards 305°
120	9	0.0-1.0		cliff top dunes
		1.0-9.0	E	fossiliferous, organic detritus
121	128	0.0-9.0	B	
122	62	0.0-6.5	E	fossiliferous
123	14	0.0-0.5	F	cryoturbated
		0.5-1.5	E	
		1.5-9.0	D	fossiliferous
		9.0-10.0	B	
		10.0-10.5	A2	
		10.5-11.0		granite, striae 305°
124	20	0.0-11.0	D	fossiliferous
125	27	0.0-2.0	D	fossiliferous
		2.0-2.5	A2	
		2.5-7.5		gneiss, striae 358°
126	31	0.0-15.0	D	fossiliferous
		15.0-17.0	C	
		17.0-17.5	B	
		17.5-18.5	A2	
		18.5-19.5		granite, striae 345°
127	22	0.0-9.0	D	fossiliferous
128	7	0.0-0.5	E	organic detritus
		0.5-6.0	D	
		6.0-6.5		covered
		6.5-7.0		gneiss, striae 325°

CHAPTER III - LATE QUATERNARY SEA LEVEL HISTORY IN THE PAULATUK TO BATHURST INLET AREA, N.W.T.

INTRODUCTION

The central mainland coast of the Northwest Territories provides the opportunity to investigate the history of postglacial sea level from Paulatuk to Bathurst Inlet (Fig. III-1), as well as the geomorphological effects of glacioisostatic emergence during and following the retreat of Late Wisconsin ice. The study area is within the northwestern region of the Laurentide Ice Sheet and forms a transect perpendicular to the western side of the M'Clintock Ice Divide where few studies are available. A series of raised glaciomarine deltas define the postglacial marine limit along coastal lowlands, whereas other marine features are associated with successively lower sea levels through to late Holocene times. The main purposes of this paper are: 1) to describe new sea level data based on regional stratigraphic and geomorphological studies, 2) to present the deglacial sequence of regional ice-front positions based on geomorphologic, stratigraphic and radiocarbon data, 3) to construct provisional relative sea level curves from regions which have been subject to a range of increasingly greater continental ice loading over a distance of 1 000 km, 4) to discuss the glacioisostatic implications of these curves, and 5) to integrate this study on a regional basis, including a comparison of emergence rates from earlier investigations within the study area and from other regions in the central Canadian Arctic.

PREVIOUS STUDIES

Raised marine deposits along the central mainland coast of the Northwest Territories have received little attention to date. The early accounts of Hanbury (1904) and O'Neill (1924) refer only briefly to the presence of marine shells and deposits, up to an elevation of 152 m a.s.l. along the Tree River and on eastern Kent Peninsula (Fig. III-1). Washburn (1947) and Fortier (1948) reported the occurrence of marine features below 152 m a.s.l. on Banks Peninsula in Bathurst Inlet. Preliminary studies of raised marine deposits in the Bathurst Inlet area (Bird,1955; Blake, 1963) referred to marine limits in the order of 200 m to 225 m a.s.l. based on the elevation of marine shells, beaches and washing limits. Craig (1960) estimated marine limit in the Coppermine region (Fig. III-1) to be 152 m a.s.l., descending to the Croker River where it was thought to approach present sea level. More recently, Kerr (1984, 1987) identified evidence of marine regression in the Richardson River basin west of Coppermine. St-Onge (1987) studied the Late Quaternary history of the Coppermine area and reassessed marine limit to be 170 m a.s.l. South of

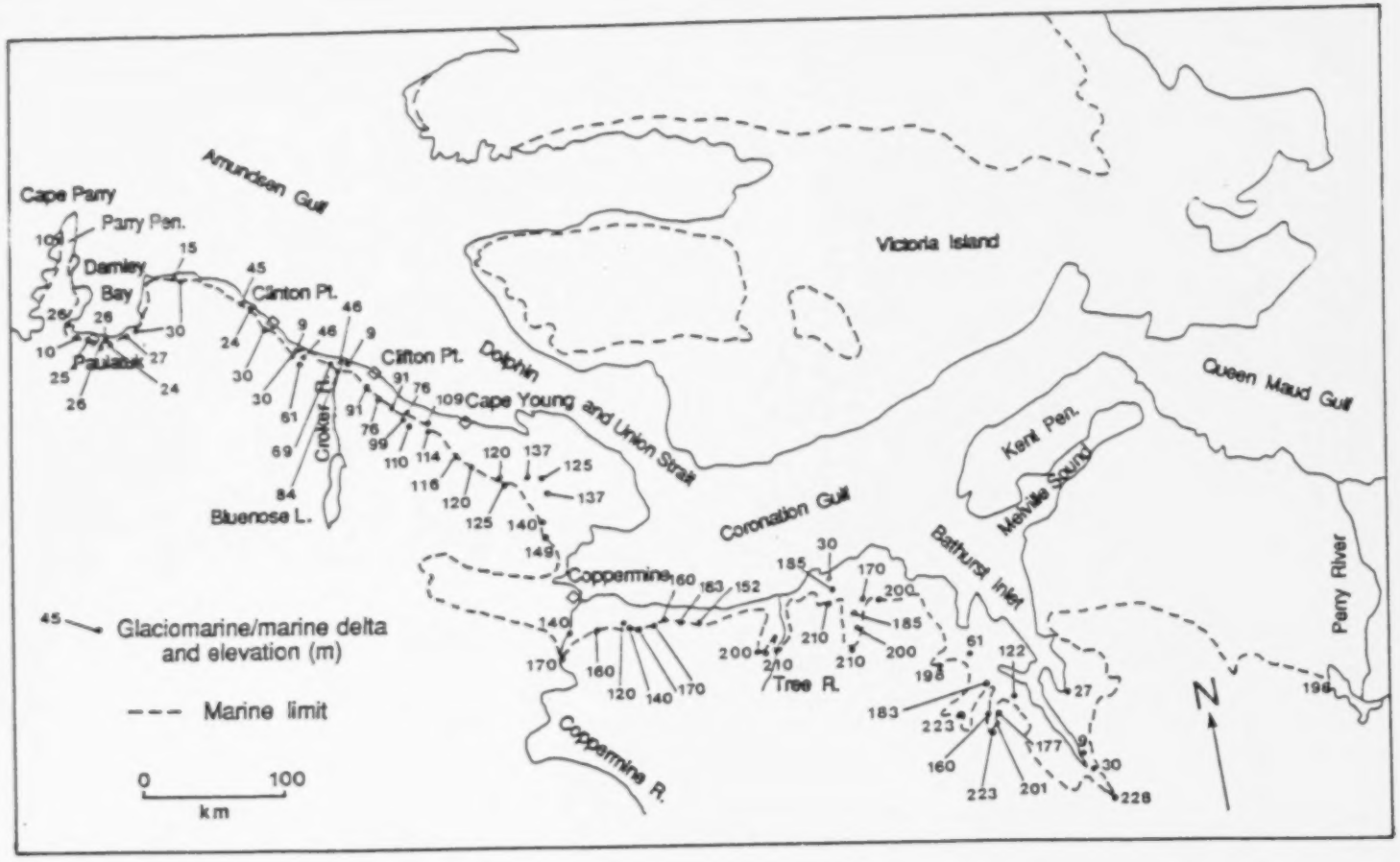

Figure III-1: Location map of the study area showing elevation of marine limit, and glaciomarine and marine deltas. Marine limit is extrapolated between deltas, strandlines and washing limits of known elevation. Data for Victoria Island modified from Sharpe (1984, 1987) and Dyke and Prest (1987a, b).

Dolphin and Union Strait (Fig. III-1), St-Onge and McMartin (1987) and McMartin and St-Onge (1990) reported marine limit below 150 m a.s.l. northwest of Coppermine, decreasing to 80 m a.s.l. northeast of Bluenose Lake. In the Darnley Bay area (Fig. III-1), Vincent (G.S.C., pers. commun., 1988) recognized raised marine deposits and shells, whereas Kerr (1989) described the stratigraphic record some of these late-glacial and postglacial sediments.

DISTRIBUTION OF GLACIOMARINE AND MARINE FEATURES

Throughout the study area, raised deltas record local marine limits (Fig. III-1). Marine limit refers to the highest shoreline established by the sea during deglaciation, which may take the form of deltas, beaches and washing limits (cf. Andrews, 1970). Elevation of these and other marine features were determined by helicopter altimeter[1] and NTS 1:50 000 and 1:250 000 scale topographic maps. High-level glaciomarine deltas, composed of pebbly sands to bouldery gravel, are frequently associated with kames and glaciofluvial outwash which can be traced inland for several kilometres. Many of these deltas exhibit collapse (slump) structures on their southern flanks suggesting that they were in contact with ice at the time of their formation (Plate III-1). During this period, the ice front terminated along the southern coastal margin, supplying sediment-laden meltwaters to the deltas prograding to the north. In the central and northern parts of Parry Peninsula, a series of north-south trending recessional moraines occur. Eskers on the east side lead up to the moraines which are breached in places. At two of these locations, deltas occur at 6 m and 10 m a.s.l. on the west side of the moraines. Similar topographic settings persisted throughout deglaciation as evidenced by comparable features south of Dolphin and Union Strait and Coronation Gulf.

The majority of these landforms are typical Gilbert-type deltas characterized by flat tops containing kettle lakes and underlain by crudely bedded gravel foresets. Both the size and number of deltas decrease significantly below marine limit towards the lower elevations of the outer coast to the north (Table III-1), a feature also noted by Bednarski (1986) on northern Ellesmere Island. These deltas form an almost continuous line along the southern shores of Amundsen Gulf, Dolphin and Union Strait, and Coronation Gulf, varying in elevation from 6 m a.s.l. to approximately 225 m a.s.l. Their distribution reflects an elevation trend which rises relatively consistently towards the east. The Laurentide Ice Sheet prevented the extensive inland penetration of late glacial marine waters in many areas along the coast, as evidenced by the distribution of deltas proximal to the coastline.

Below marine limit, deep-water marine silt and clay conformably overlie glaciomarine and

[1]probable accuracy ± 6 metres (Stan Smith, Canadian Helicopters, pers. commun., 1993)

Plate III-1: Kettled ice-contact glaciomarine delta with slump scars to the south (left) and arcuate front to the north, 210 m a.s.l. (section 101).

Table III-1. Regional and altitudinal distribution of deltas.

Region	Total number of deltas	Number of deltas within 20 metres elevation of local marine limit	Marine limit (metres a.s.l.)
Paulatuk	7	5	25
Clinton Point	11	8	55
Clifton Point	6	5	90
Cape Young	7	7	125
Coppermine	10	7	170
Bathurst Inlet	15	11	225

glaciofluvial deposits and till. Extensive raised marine silty-clay deposits dominate many low-lying coastal areas (<100 m a.s.l.). South of Dolphin and Union Strait, Coronation Gulf and Queen Maud Gulf (Fig. III-1), they may attain thicknesses of 15 m to 20 m where they blanket large, broad basins. At higher elevations, they infill the many small depressions between bedrock outcrops which characterize the upland topography further inland.

DeGeer moraines, which are restricted to lower elevations, are common indicators of ice margins that terminated along submerged coasts (Plate III-2). These moraines occur in the region southwest of Dolphin and Union Strait and east of the Tree River. Most trend southwest-northeast and are associated with ice fronts which receded towards the east. They generally consist of a diamicton with a sand-silt matrix with abundant rounded to angular cobbles. Their upper surfaces commonly consist of bouldery lag deposits resulting from the winnowing of fines by wave action during marine regression.

In contrast, strandlines are found throughout the area. However, they are poorly developed at higher elevations, and rare to absent near marine limit (Plate III-3). The greatest concentration of well-defined beaches are typically found in the many small coastal embayments of the mainland, as well as on the offshore islands. Beaches occur a few ten's of metres above present sea level (Plate III-4) from which they may form a continuous flight of ridges. Many consist of poorly sorted, subangular gravels and cobbles, as well as angular clasts of predominantly local lithologies, and are less than 1 m in height. They are best developed in areas where sandy gravel subaqueous outwash was deposited below marine limit and subsequently reworked by marine waters as sea level fell.

Marine deltas were formed as sea levels fell to progressively lower elevations. The majority are found along present-day rivers and are related to larger, ancestral rivers. From Darnley Bay to Bathurst Inlet, most major drainage basins possess raised marine deltas, varying in elevation from 6 m to approximately 183 m, respectively.

LATE QUATERNARY DEGLACIATION

Successive deglacial Laurentide ice margins are presented in Figure III-2. Ice margins are based on the present study and previous interpretations by Dyke and Prest (1987a, b), Klassen (1971), McMartin and St-Onge (1990), Sharpe (1992) and Vincent (1984). Selected existing radiocarbon dates (Table III-2) provide minimum ages for deglaciation of the field area. Approximately seven major provisional ice front positions have been identified and assigned tentative ages for the purpose of discussion. These ice margins have been defined on the basis of landform such as moraines, kames, glaciofluvial outwash, meltwater channels and washing limits.

Plate III-2: DeGeer moraines, approximately 50 m in length, east of the study area south of Queen Maud Gulf; view is to the northeast.

Plate III-3: Glaciomarine delta at 210 m a.s.l. in which lower part of the delta front has been reworked into beaches during emergence; view is to the east. Note helicopter for scale, (section 101).

Plate III-4: Flight of raised beaches, from present-day sea level to 50 m a.s.l., southeast of Hepburn Island; view is to the southeast. Beaches terminate at base of prominent fault scarp at top left.

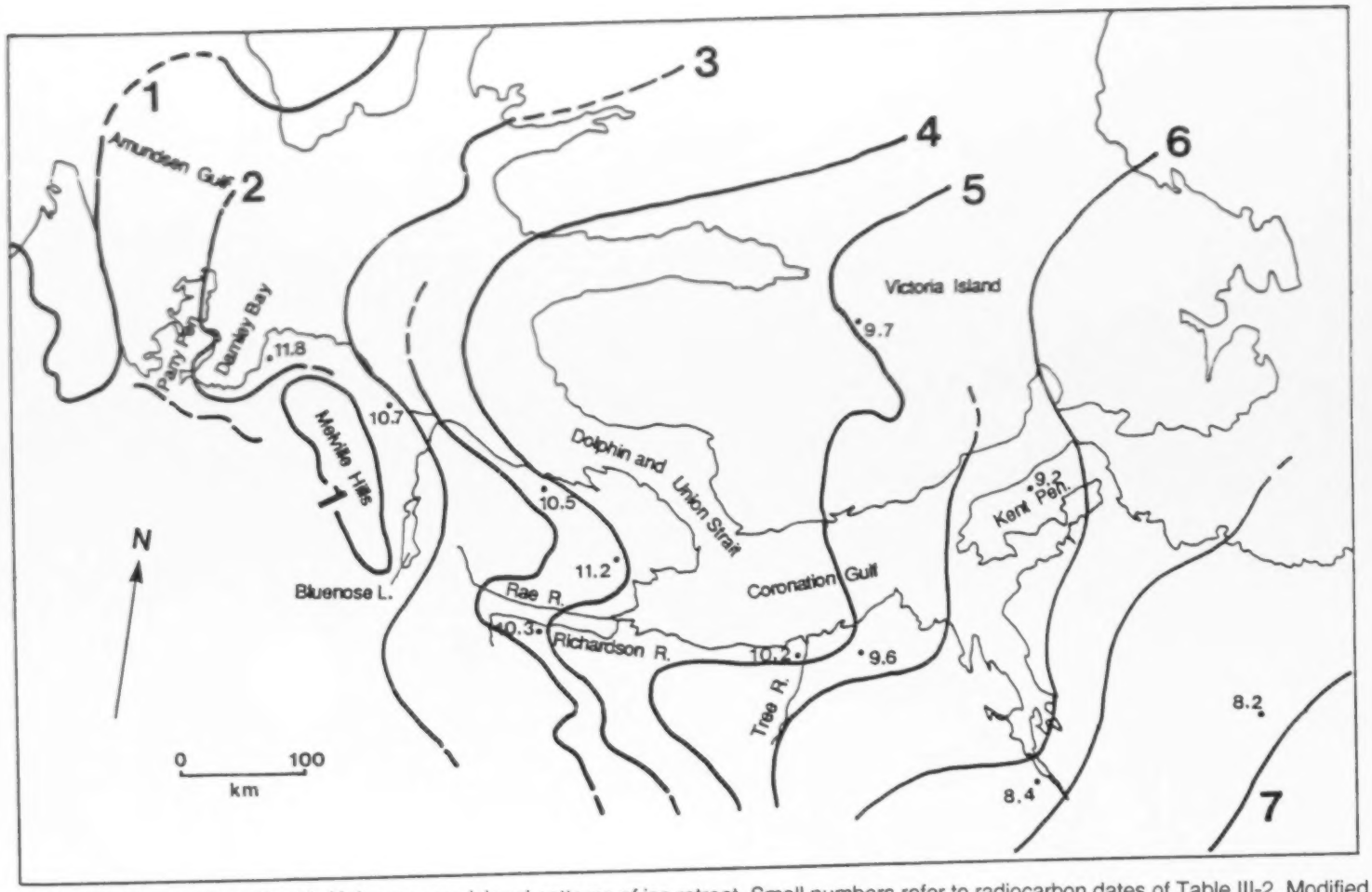

Figure III-2: Late Wisconsin and early Holocene provisional patterns of ice retreat. Small numbers refer to radiocarbon dates of Table III-2. Modified in part from Dyke and Prest (1987a, b), McMartin and St-Onge (1990) and Sharpe (1992).

Table III-2: Selected radiocarbon dates from the study area. See Figure III-2 for locations.

No.	Laboratory No.	Age (yrs BP)	Elevation (m)	Material dated	Reference
1	AECV-643Cc	11790 ± 160	5	*Hiatella arctica*	This paper
2	GSC-4318	10700 ± 100	30	*Hiatella arctica*	St-Onge (pers. comm.)
3	I(GSC)-25	10530 ± 260	74	marine shells	Craig, 1960
4	GSC-3663	10300 ± 240	90	*Macoma calcarea*	Mercier, 1984
5	TO-1231	11170 ± 80	125	*Portlandia arctica*	St-Onge (pers. comm.)
6	I(GSC)-17	10215 ± 220	85	*Macoma calcarea*	Craig, 1960
7	GSC-42	9710 ± 150	158	marine shells	Dyke and Fyles, 1963
8	GSC-3584	9620 ± 130	198	*Hiatella arctica*	Blake, 1983
9	GSC-125	9190 ± 210	186	*Mya truncata*	Blake, 1963
10	GSC-115	8370 ± 100	198-204	*Hiatella arctica*	Blake, 1963
11	GSC-110	8160 ± 140	183	*Hiatella arctica*	Blake, 1963

Position 1, outside of the study area, delineates the Late Wisconsin glacial limit (18 ka). As inferred from Dyke and Prest (1987a), the Late Wisconsin ice remained relatively stationary for about 5 000 years (18 to 13 ka). Some of the moraines of Parry Peninsula and meltwater channels in the western Melville Hills formed subsequently (position 2). At position 2, marine limit was established at 10 m a.s.l. on the north end of Parry Peninsula between 13 and 11.8 ka. Although no radiocarbon data are available to date this event, it must predate 11.8 ka (No. 1, Table III-2, Figure III-2), the age of marine sediments overlying glacial diamicton on the east side of Darnley Bay. Glaciomarine deltas south and east of Darnley Bay at 25 m to 30 m a.s.l. respectively mark the local marine limit established during deglaciation.

Calving of the ice lobe occupying Amundsen Gulf as it retreated from position 1 to position 2 created a drawdown in which active ice flowed west into the gulf and southwest into Darnley Bay, forming drumlins east of the bay. St-Onge and McMartin (1987) similarly interpreted drumlin fields east of Bluenose Lake to be the result of westward flow being redirected towards a calving bay in Amundsen Gulf and undergoing rapid extensive flow. Kames and outwash fans northwest, north and east of the Melville Hills indicate that the ice lobe receded to successively lower elevations. Position 3 may coincide with the Inman River Phase of McMartin and St-Onge (1990), and likely dates between 11.8 and 11.2 ka (Nos. 1 and 5, Table III-2, Figure III-2). The association of position 3 with the ice marginal positions south of Bluenose Lake identified by Prest (1985) is uncertain as no radiometric dates are available.

The ice front between positions 3 and 4 corresponds to moraines in the region north of the Rae River, whereas position 4 is associated with a series of arcuate moraines southwest of Dolphin and Union Strait. During ice retreat from positions 3 to 4, northwestward flowing ice separated into two lobes occupying Dolphin and Union Strait, and the basin of the Rae and Richardson rivers, respectively. Surging of the ice lobes is indicated by northwest trending drumlins modified by west-northwest ice flow resulting from a change in ice flow caused by drawdown into a calving bay further west (McMartin and St-Onge, 1990). South of Dolphin and Union Strait, the marine incursion took place before 11.2 ka (No. 5, Table III-2). Ice attained position 4 by 11 ka. This reconstruction differs from the model proposed by Dyke and Prest (1987a) who show a slightly more extensive margin.

Following a minor retreat of the ice front from position 4, marine waters inundated the basin of the Rae and Richardson rivers from the northeast along a corridor between the local uplands and the ice occupying Dolphin and Union Strait. The marine invasion occurred before 10.3 ka, the oldest available date obtained on marine shells at 90 m a.s.l. (No. 4, Table III-2). During this period of ice retreat, ice originating from Victoria Island flowed across Dolphin and Union Strait towards the southwest. This flow crosscuts striae originating from the previous northwestward flow (McMartin and St-Onge, 1990). A series of discontinuous, arcuate morainic ridges mark the

northeastward retreat of the Victoria Island ice lobe both above and below the local marine limit (130 m - 140 m a.s.l.). Ridges composed of stratified sandy gravel are interpreted as subaqueous outwash deposits. Those formed of matrix-supported diamicton are inferred to be moraines. Two glaciomarine ice-contact deltas at 137 m a.s.l. associated with these ridges were constructed in the narrow arm of the sea along the south shore of Dolphin and Union Strait. To the east of these moraines, several smaller ridges are found, and are interpreted as DeGeer moraines formed by the ice front which terminated in the sea. These smaller moraines are superimposed on drumlins perpendicular to their long axis (Plate III-5).

Invasion of the sea west of Coronation Gulf led to rapid calving of the ice mass and a reduction of the two ice lobes of position 4. This allowed the sea to occupy the coastal lowlands south of Coronation Gulf. At Coppermine, marine limit was established at 170 m a.s.l. (St-Onge, 1987). Two radiocarbon dates indicate that the ice margin of position 5 is ca. 10 ka (Nos. 6 and 7, Table III-2). The ice front must have been located west of the 9.7 ka site on Victoria Island, and east of the 10.2 ka site at Tree River on the mainland where marine limit is 200 m a.s.l. The ice margin between positions 5 and 6 probably formed between 9.6 ka (No. 8, Table III-2) and 9.2 ka (No. 9, Table III-2). The ice sheet continued its eastward retreat so that by 9 ka, it had reached position 6 in the eastern region of Bathurst Inlet. During this period, a series of ice-contact glaciomarine deltas with collapse structures on their landward side were formed along the ice margin.

Position 6 cannot be assigned a specific age, but it postdates 9.2 ka and predates 8.4 ka (No. 10, Table III-2). The period from positions 6 to 7 is characterized by rapid ice retreat after 9 ka (Nos. 10 and 11, Table III-2), although at least one period of still stand occurred during which moraines were built southeast of Kent Peninsula. Similarly, between 9 ka and 8.4 ka, Laurentide Ice retreated from central Boothia Peninsula a few hundred kilometres to the east of the study area, south to the mainland coast (Dyke, 1984). Rapid deterioration of Laurentide ice was hastened by the surrounding marine environment. Position 7 represents the last ice marginal position in the study area and predates 8.2 ka (No. 11, Table III-2). This ice front is associated with a large end moraine known as the MacAlpine Moraine (Blake, 1963) which extends for 320 km outside of the study area. Whether this moraine is related to the Chantry Moraine System dated at 8.5 ka to 8.4 ka (Dyke, 1984) south of Boothia Peninsula is unknown at present.

CONSIDERATIONS FROM GENERAL THEORY

Relative sea level curves can provide important information on the interaction between glacial unloading and glacioisostatic recovery (Andrews, 1968; Andrews and Barnett, 1972). Detailed discussions of sea level histories predicted by viscoelastic models are presented by Clark

Plate III-5: DeGeer moraines superimposed perpendicular to drumlins, southwest of Dolphin and Union Strait; centre drumlin is 0.5 km in length; view is to the west.

et al., (1978), Farrell and Clark (1976), Peltier (1982, 1989) and Quinlan and Beaumont (1981). More recently, a revised viscoelastic Earth structure was employed in the construction of the glaciation model ICE-3G and in geographic variations in relative sea level predictions during the last 18 000 years (Tushingham and Peltier, 1991). As summarized by Peltier (1989), the dominant contribution to load-induced deformation is due to viscous flow within the mantle. The higher the viscosity of the earth's mantle, the slower will be the relaxation of the viscous component of the deformation following glacial unloading. This results in delayed rebound and inflow of viscous mantle material. Tushingham and Peltier (1991) demonstrated that the shape of a sea level curve depends on the proximity to the ice load, but the time of deglaciation is also a factor, as this determines how much interference will occur between eustatic and glacioisostatic processes. According to Walcott (1970), the Laurentide Ice Sheet generated an ice-marginal depression calculated to extend 180 km past its margin beyond which crustal displacement becomes positive (forebulge of 18 m based on ice thickness of 1 800 m). The forebulge is formed of sublithospheric material extruded from beneath isostatically subsiding ice sheets, and is progressively displaced as a wave beyond the advancing front (Boulton, 1990). As the ice sheet melts, isostatic disequilibrium causes mantle material to flow back from the forebulge towards the rebounding ice centre (Hill *et al.*, 1985). Forebulge migration continues long after the period of deglaciation, as suggested by Quinlan and Beaumont (1981) for Atlantic Canada, based on sites which initially underwent emergence and are presently experiencing submergence.

Clark *et al.*, (1978) provide a theoretical framework illustrating variations in isostatic adjustments along a transect from a heavily loaded site to one beyond the glacial limit. Sites on the distal side of the forebulge (Zone II), beyond the ice margin, will experience continuous submergence throughout migration of the bulge, in the form of a marine transgression during and following deglaciation. In the region nearer to the maximum extent of an ice sheet (transition of ZoneII/I), a site will be subjected to emergence which is eventually replaced by submergence. Because of the migration of the collapsing forebulge, the timing of emergence/submergence is dependent on position along the transect. Formerly ice-covered areas show ongoing, net emergence which progressively increases towards centres of greatest ice loading within the ice margin (Zone I). The early form of emergence curves as defined by Andrews (1970), reflecting the exponential decrease with time, is associated with Zone I.

The effects of glacioisostatic and eustatic components are not easily distinguished. As eustatic sea level changes over time are difficult to establish and not globally uniform (Quinlan and Beaumont, 1981; Andrews, 1989; England *et al.*, 1991; England , 1992; Eyles and Eyles, 1992), they are not considered here for regional comparison with other emergence curves which have not been eustatically corrected. However, recent eustatic sea level calculations (Tushingham and Peltier, 1991) provide evidence for non uniform sea level rise during the last 18 000 years.

RELATIVE SEA LEVEL HISTORY

In order to determine relative sea level history, seven geographical regions have been defined in the study area based on the availability of radiocarbon dates. Seven new provisional sea level curves were constructed and each has undergone increasingly greater uplift, from Paulatuk, eastward to southern Bathurst Inlet (Figures III-3a to 3g). The Paulatuk area, farthest away from the centre of loading, exhibits the least amount of glacial isostatic recovery. Sites closer to greater loading (Bathurst Inlet) exhibit the most. A number of marine features such as deltas, beaches and intertidal deposits were used to identify specific sea levels. Marine limit in these regions is diachronous, ranging from 12.5 ka or older in the Paulatuk-Parry Peninsula region to 9-8.7 ka in the southeastern Bathurst Inlet area. A list of radiocarbon dates presented in Table III-3 provides the marine chronology, and their locations are given in Figure III-4. Dating of postglacial sea levels is incomplete and because samples used to construct each sea level curve are distributed over geographic regions of various sizes, only preliminary curves are presented. Furthermore, many existing dates are on marine shells that cannot be directly associated to specific sea levels. In most cases, only part of an emergence curve can be plotted with confidence. Few dates exist between 2 and 7 ka, and the majority of samples do not underlie a recognizable relative sea level. In addition, no datable material was found at or near marine limit, and varying lengths of time exist (up to several hundred years) between the formation of marine limit and the first appearance of marine fauna. However, this does not preclude their existence at or near marine limit, as they may not yet have been recorded. These are recurring problems in many sea level studies in the Arctic (Dredge and Cowan, 1989). Wherever possible, estimates of probable sea level elevations related to individual dates have been attempted as relative sea level. Solid curves in Figures III-3a to III-3g are considered to be well controlled, whereas segmented portions are extrapolations through intervals with little control.

PAULATUK AREA

This most westerly site is characterized by two of the oldest radiocarbon dates from the study area: 11 790 ± 160 BP (No. 1, Table III-3) and 11 280 ± 100 BP (No. 2, Table III-3). These dates were obtained on shells from 5 and 6 m a.s.l., respectively, and record an early deglaciation. The elevation of marine limit is estimated to be about 25 m based on nearby deltas and is thought to have been established after 13 000 BP but prior to 11 800 BP. At lower elevations (Fig. III-3a), younger dates on wood and peat from fluvial deposits overlying deltaic sediments (No. 3, Table III-3) and on peat overlying alluvial fan deposits (No. 3, Table III-3), help bracket the sea level curve

Table III-3. Selected radiocarbon dates for emergence studies

Reference number	Laboratory number	Material	Stratigraphic context	Age (yrs BP)	Elevation (m)	Relative sea level (m)	Reference	Lat. N	Long. W
PAULATUK REGION (marine limit 25 m a.s.l.)									
1	AECV-643Cc	*Hiatella arctica*	offshore clay	11790 ± 160	5	>5-≤20	This paper	69°35'	123°07'
2	TO-217	*Hiatella arctica*	surface	11280 ± 100	6	>6-≤10	J.S.Vincent (pers. comm., 1989)	69°22.1'	123°34.6'
3	GSC-4143	*Salix sp.*	fluvial	9400 ± 120	1	≤1	J.S.Vincent (pers. comm., 1989)	69°20.6'	124°02.6'
4	GSC-4480	peat	fluvial	9600 ± 100	2.5	≤2.5	J.S.Vincent (pers. comm., 1989)	69°22.3'	124°30'
5	GSC-4410	peat	fluvial	5100 ± 100	2	≤2	J.S.Vincent (pers. comm., 1989)	69°21.6'	124°03.5'
CLINTON POINT REGION (marine limit 50 m a.s.l.)									
6	AECV-642Cc	*Hiatella arctica*	surface	10340 ± 140	24	>24-≤30	This paper	69°38'	121°03'
7	AECV-644Cc	*Hiatella arctica*	surface	10840 ± 180	16	>31-≤50	This paper	69°46'	121°40'
8	AECV-645Cc	*Hiatella arctica*	offshore clay	10410 ± 150	18	>18-≤30	This paper	69°38'	121°02'
9	AECV-462Cc	*Hiatella arctica*	surface	10000 ± 170	25	>25-≤30	This paper	69°24'	120°20'
10	AECV-444Cc	*Hiatella arctica*	surface	10620 ± 160	30	>30-≤35	This paper	69°24'09"	120°16'36"
11	GSC-4318	*Hiatella arctica*	surface	10700 ± 100	30	>30-≤45	D.A. St-Onge (pers. comm., 1989)	69°24'30"	120°18'45"
12	GSC-4339	*Hiatella arctica*	offshore clay	10600 ± 120	31	>31-≤40	D.A. St-Onge (pers. comm., 1989)	69°23'18"	120°13'29"
13	GSC-4347	*Hiatella arctica*	surface	9810 ± 120	10	>10-≤30	D.A. St-Onge (pers. comm., 1989)	69°24'39"	120°17'21"
CLIFTON POINT REGION (marine limit 90 m a.s.l.)									
14	AECV-473Cc	*Hiatella arctica*	surface	9600 ± 140	45	>45-≤50	This paper	69°07'13"	118°31'54"
15	AECV-712Cc	*H. arctica, M. balthica*	surface	9300 ± 540	30	>30-≤40	This paper	69°07'31"	118°30'55"
16	GSC-4390	*Hiatella arctica*	surface	10700 ± 100	61	>61-≤70	D.A. St-Onge (pers. comm., 1989)	69°08'23"	118°41'34"
17	GSC-4402	*Hiatella arctica*	offshore clay	10300 ± 100	47	>47-≤65	D.A. St-Onge (pers. comm., 1989)	69°08'05"	118°35'45"
18	GSC-4424	*Hiatella arctica*	surface	10400 ± 100	25	>25-≤60	D.A. St-Onge (pers. comm., 1989)	69°09'32"	118°38'17"
19	GSC-4425	*Clinocardium ciliatum*	offshore clay	8890 ± 110	13	>13-≤35	D.A. St-Onge (pers. comm., 1989)	69°11'32"	118°38'49"
W. BERNARD HR. REGION (marine limit 135 m a.s.l.)									
20	AECV-646Cc	*Mytilus edulis*	surface	5660 ± 110	18	>18-≤20	This paper	68°44'	115°37'
21	AECV-717Cc	*Clinocardium ciliatum*	surface	7250 ± 180	15	>15-≤50	This paper	68°45'	115°38'
22	GSC-4727	*Hiatella arctica*	offshore clay	9930 ± 100	100	>100-≤115	D.A. St-Onge (pers. comm., 1989)	68°27'58"	115°34'34"
23	GSC-4749	*Hiatella arctica*	surface	9620 ± 90	105	>105-≤110	D.A. St-Onge (pers. comm., 1989)	68°32'32"	115°05'40"
24	GSC-4846	*Hiatella arctica*	surface	9610 ± 80	100	>100-≤105	D.A. St-Onge (pers. comm., 1989)	68°30'33"	115°10'53"
25	GSC-4848	*Hiatella arctica*	surface	9700 ± 80	95	>95-≤105	D.A. St-Onge (pers. comm., 1989)	68°27'26"	115°21'23"
26	GSC-4849	*Hiatella arctica*	surface	9690 ± 150	80	>80-≤110	D.A. St-Onge (pers. comm., 1989)	68°39'31"	115°26'46"
27	GSC-4917	*Hiatella arctica*	surface	9850 ± 80	99	>99-≤110	I. McMartin (pers. comm., 1994)	68°39'21"	115°46'40"

Table III-3. Selected radiocarbon dates for emergence studies

Reference number	Laboratory number	Material	Stratigraphic context	Age (yrs BP)	Elevation (m)	Relative sea level (m)	Reference	Lat. N	Long. W
28	GSC-4926	*Hiatella arctica*	surface	10100 ± 90	85	>85-≤115	D.A. St-Onge (pers. comm., 1989)	68°48'15"	115°39'12"
RICHARDSON BAY REGION (marine limit 160 m a.s.l.)									
29	GSC-39	marine shells	offshore clay	9440 ± 120	98	>98-≤105	Dyck and Fyles, 1963	67°57'	115°38'
30	GSC-1517	peat	beach surface	2500 ± 140	19	<19	Lowdon and Blake, 1973	67°50'	115°16'
31	GSC-1820	wood	beach surface	3700 ± 80	16	<16	Lowdon and Blake, 1979	67°50'	115°19'
32	GSC-3327	*Macoma calcarea*	surface	9820 ± 90	100	>100-≤125	St-Onge and Bruneau, 1982	67°43'48"	115°25'34"
33	GSC-3941	*Mya truncata*	offshore clay	9430 ± 110	73	>73-≤90	Kerr, 1987	67°48'	116°40'
34	GSC-4009	*Salix sp.*	littoral	6100 ± 80	23	>23-≤25	Kerr, 1987	67°48'	116°11'
35	AECV-403Cc	*H. arctica, M. truncata*	offshore silt	9800 ± 140	73	>73-≤95	This paper	67°48'	116°40'
NORTHERN BATHURST INLET (marine limit 210 m a.s.l.)									
36	GSC-125	*Mya truncata*	surface	9190 ± 210	186	>186-≤195	Blake, 1963	68°40'	107°03'
37	GSC-737	*H. arctica, M. truncata*	surface	8720 ± 150	143	>143-≤180	Lowdon et al., 1967	68°06'30"	106°54
38	GSC-644	*H. arctica, M. truncata*	surface	9170 ± 160	176	>176-≤190	Lowdon et al., 1967	67°47'	109°48'
39	GSC-152	organics	sublittoral	3070 ± 140	7.3	>7.3-≤15	Blake, 1963	68°11'	106°16'
40	GSC-158	*M. balthica, M. truncata*	sublittoral	2510 ± 158	8	>8-≤10	Blake, 1963	68°08'	106°16'
41	GSC-224	*shell fragments, M. edulis*	marine sand	7480 ± 160	102	>102-≤130	Lowdon et al., 1967	67°27'30"	108°06'
42	GSC-302	calcareous algae	surface	4190 ± 130	27	>27-≤37	Lowdon et al., 1967	67°29'30"	108°08'
43	GSC-303	*H. arctica, M. truncata*	surface	4110 ± 150	27	>27-≤37	Lowdon et al., 1967	67°29'30"	108°08'
44	GSC-344	*shell fragments, M. edulis*	surface	8360 ± 150	146	>146-≤170	Lowdon et al., 1967	67°27'30"	108°12'
45	GSC-594	*Hiatella arctica*	surface	8220 ± 160	146	>146-≤160	Lowdon et al., 1967	67°27'30"	108°12'
46	GSC-604	*Mytilus edulis*	beach surface	8070 ± 160	152	>152-≤157	Lowdon et al., 1967	67°34'30"	106°31'30"
47	GSC-610	*Hiatella arctica*	surface	4960 ± 140	21	>21-≤55	Lowdon et al., 1967	67°27'30"	108°10'30"
48	GSC-615	*Hiatella arctica*	surface	8200 ± 140	131	>131-≤160	Lowdon et al., 1967	67°25'	107°35'
49	GSC-645	*Balanus crenatus*	surface	7990 ± 150	71	>71-≤150	Lowdon et al., 1967	67°27'30"	108°06'
50	GSC-646	*Hiatella arctica*	surface	7730 ± 160	58	>58-≤148	Lowdon et al., 1967	67°33'30"	108°08'
51	AECV-445C	wood	foresets	3850 ± 210	27.5	>27.5-≤30	This paper	67°52'	110°35'
52	AECV-946Cc	*Mytilus edulis*	sublittoral	2330 ± 90	5	>5-≤8	This paper	68°12'	106°18'
SOUTHERN BATHURST INLET (marine limit 225 m a.s.l.)									
53	GSC-137	*Mytilus edulis*	bottomsets	1850 ± 140	7	>7-≤9	Blake, 1963	66°49'	107°06'
54	GSC-138	wood	sublittoral	2170 ± 140	5.8	>5.8-≤10	Blake, 1963	68°11'	106°16'
55	GSC-115	*H. arctica, Mya sp.*	offshore silt	8370 ± 140	186	>186-≤215	Blake, 1963	66°32'	107°43'
56	GSC-359	*Hiatella arctica*	beach surface	8060 ± 140	143	>143-≤195	Dyck et al., 1966	66°42'	107°55'

Table III-3. Selected radiocarbon dates for emergence studies

Reference number	Laboratory number	Material	Stratigraphic context	Age (yrs BP)	Elevation (m)	Relative sea level (m)	Reference	Lat. N	Long. W
57	GSC-785	*P. arctica, M. calcarea*	offshore clay	2280 ± 150	1.4	>1.4-≤12	Lowdon et al., 1968	66°49'30"	107°05'
58	GSC-2671	*Salix sp.*	foresets	3490 ± 70	23	>23-≤33	Blake, 1987	66°17.8'	107°05.9'
59	AECV-446Cc	*H. arctica, M. truncata*	beach surface	7720 ± 140	177	>177-≤182	This paper	66°28'	107°40'
60	AECV-447Cc	*Astarte montagui*	offshore silt	2620 ± 110	1.5	>1.5-≤17	This paper	66°49'	107°07'
61	AECV-448C	wood	foresets	3080 ± 110	20	>20-≤29	This paper	66°19'	107°05'

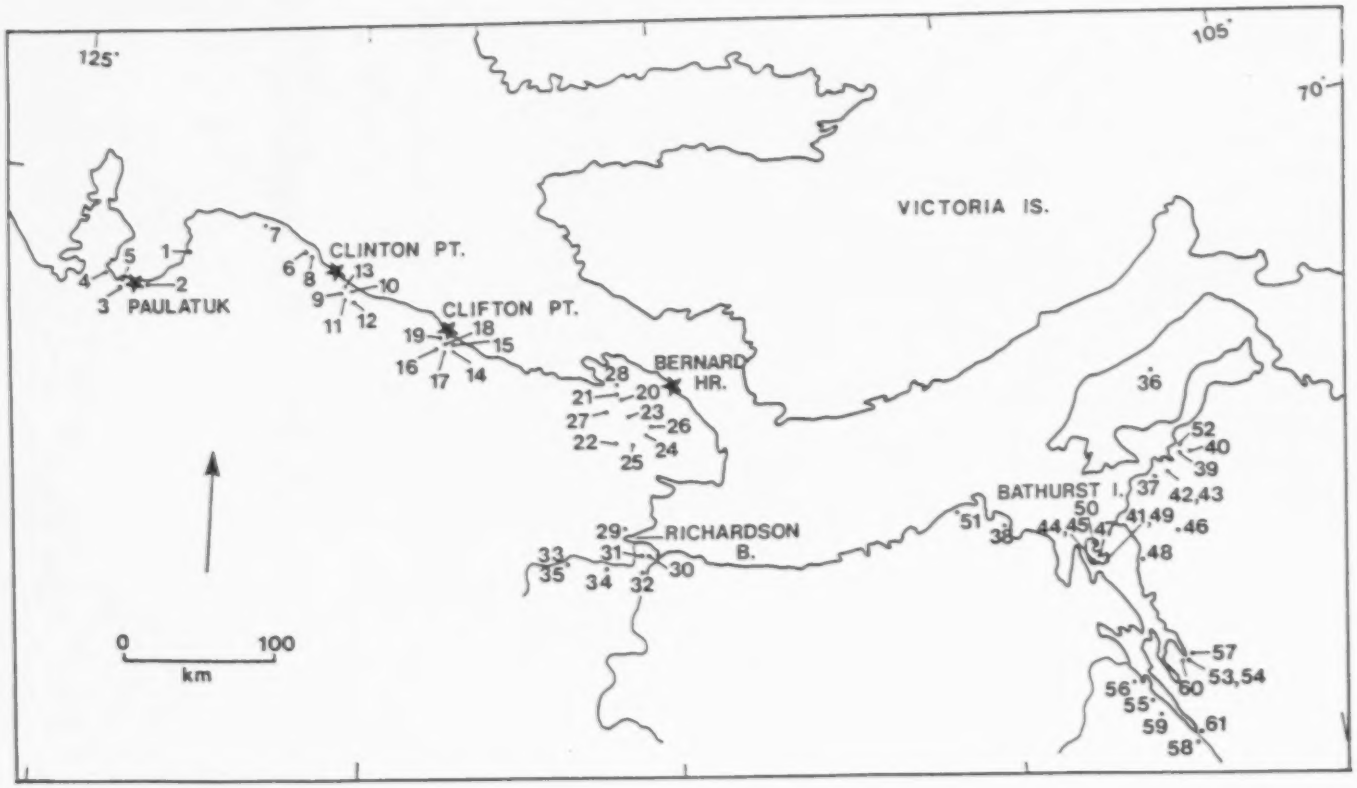

Figure III-4: Location of radiocarbon dates used for relative sea level curves.

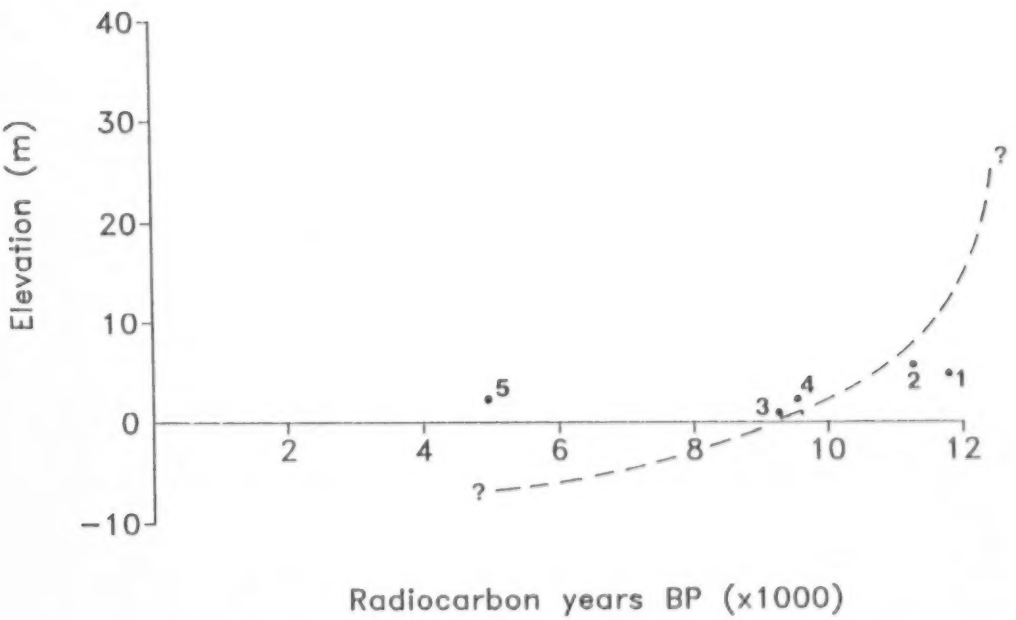

Figure III-3a: Relative sea level curve for the Paulatuk area.

in early Holocene times. Sea level was likely below 10 m a.s.l. by about 11 500 BP and had regressed to below 1 m by 9 400 BP. A date of 5 100 ± 100 BP (No. 5, Table III-3) obtained from peat unconformably overlying older deltaic deposits at 2-3 m a.s.l. also suggests that sea level remained below this elevation through the middle Holocene, although its exact position is unknown (Fig. III-3a).

At present, the middle to late Holocene database is insufficient to resolve the sea level history for this period. However, given current glacioisostatic models, the migration of the forebulge into this region would result in the Paulatuk area undergoing submergence, possibly beginning around 5 ka, and continuing to the present. This would explain why marine shells younger than 9 000 BP are apparently absent at low elevations, i.e., because they occur below present sea level.

CLINTON POINT AREA

Marine limit around Clinton Point is 50 m a.s.l. and is defined by ice-contact deltas deposited by 12 000 BP (Fig. III-3b), based on the regional pattern of deglaciation (see above). The oldest date of 10 840 ± 180 BP (No. 7, Table III-3) was collected at the surface (16.5 m a.s.l.) and must be associated with a water plane greater than 31 m a.s.l. because three younger dates (Nos. 10, 11 and 12, Table III-3) were collected at 30 m to 31 m a.s.l. Shells from sublittoral sediments at 22 m a.s.l. date 10 410 ± 150 BP (No. 8, Table III-3) and, based on Figure III-3b, may relate to a former sea level at about 30 m a.s.l. A date of 10 000 ± 170 BP (No. 9, Table III-3) obtained on shells may provide a close approximation for the age of a nearby delta marking a sea level at 25 m a.s.l. Dates from the lower elevations (Nos. 6 and 13, Table III-3) cannot be used to precisely define sea levels at these times, as they were surface collections from wave-washed deposits. Widespread shingle beaches, washed till and extensive rock outcrops below 10 m a.s.l. make it difficult to locate marine shells for dating. The lower half of the emergence curve cannot be drawn due to the existing lack of data.

CLIFTON POINT AREA

Two ice-contact deltas record marine limit at 90 m a.s.l. around Clifton Point (Fig. III-3c). The highest elevation from which marine shells were collected is 61 m a.s.l. (No. 16, Table III-3). These shells occur on the surface and date 10 700 ± 100 BP, providing a minimum age for local marine limit. The regional pattern of deglaciation, however, suggests the initial marine incursion may have taken place as early as 11 500 BP. The successively younger dates of 10 400 ± 100 BP (No. 18, Table III-3) at 25 m a.s.l. and 10 300 ± 100 BP (No. 17, Table III-3) at 47 m a.s.l. do not

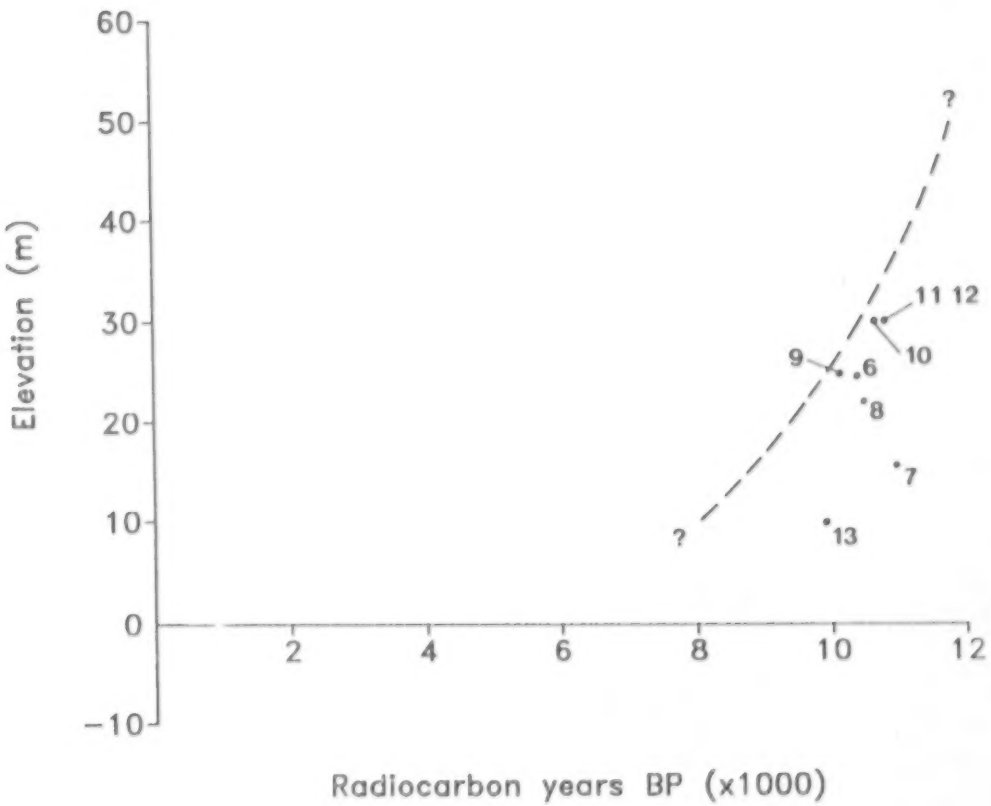

Figure III-3b: Relative sea level curve for the Clinton Point area.

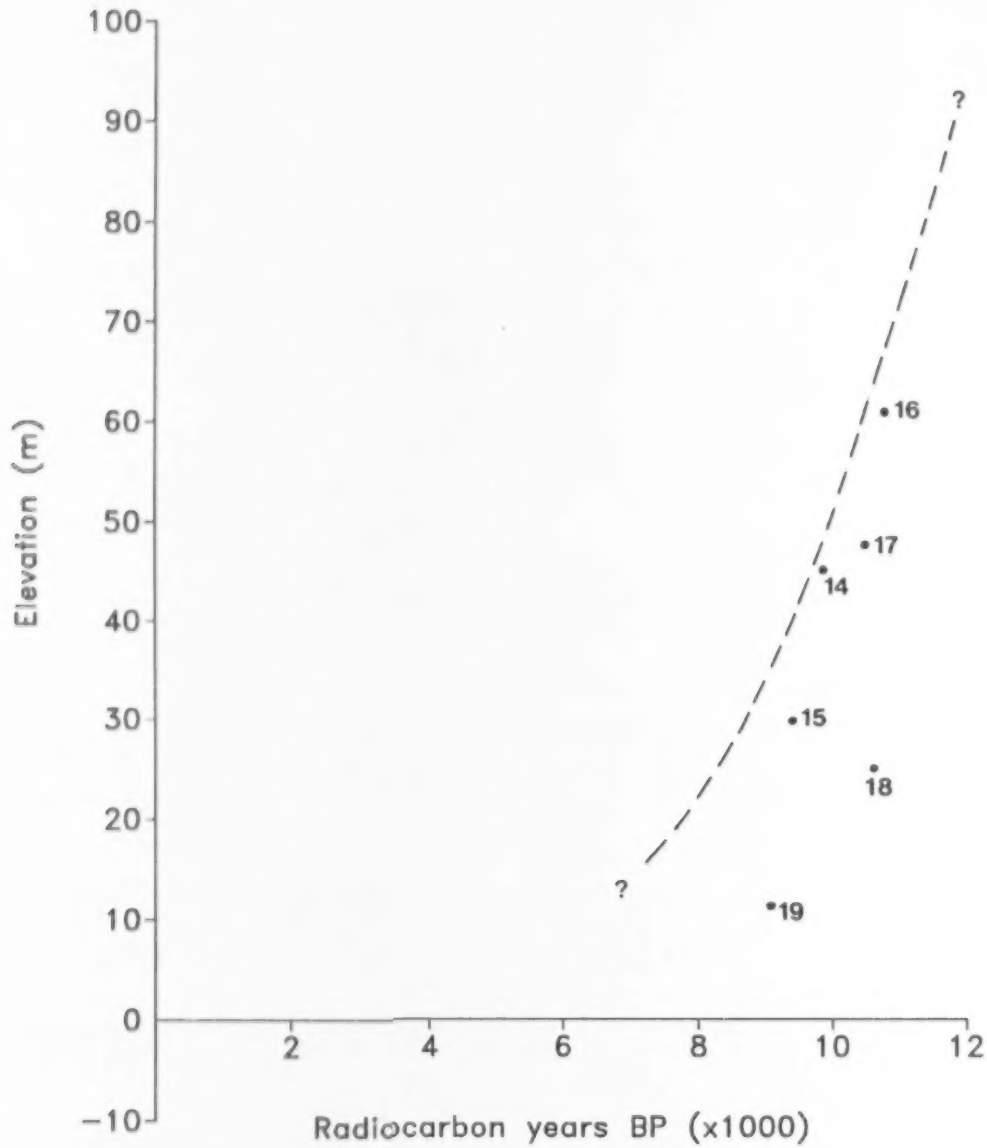

Figure III-3c: Relative sea level curve for the Clifton Point area.

coincide with their former sea levels, but rather, as seen in Figure III-3c, lived in at least 35 m and 20 m of water, respectively.

Two younger dates help to constrain the emergence for Clifton Pt. A date of 9 600 ± 140 BP (No. 14) was obtained on shells of *Hiatella arctica*, possibly related to a sandy gravel beach at 50 m a.s.l., whereas the estimated sea level for a *Macoma balthica* and *Hiatella arctica* date of 9 300 ± 540 (No. 15) coincides with a sandy gravel terrace at approximately 40 m a.s.l. As in the Clinton Point area, marine shells at lower elevations (<10 m) have not been dated. The youngest date in the region (8.9 ka) was obtained on *Clinocardium ciliatum* (No. 19) at 13 m a.s.l. and indicates a sea level several metres above the actual collection site. As there are insufficient data to establish the middle and late Holocene segments of the curve, these portions have been extrapolated from Clinton Pt. and the west Bernard Harbour area.

WEST BERNARD HARBOUR AREA

The local marine limit in the west Bernard Harbour area is 135 m a.s.l. and was established by 11 000 BP (Fig. III-3d), based on a date of 11.2 ka (TO-1231) which falls outside (to the southwest) of this particular area. The oldest radiocarbon date on marine shells is 10 100 ± 90 BP (No. 28, Table III-3) at 85 m a.s.l. This date, however, together with 9930 ± 100 BP (No. 22), 9700 ± 80 BP (No. 25), 9690 ± 150 BP (No. 26) and 9850 ± 80 BP (No. 27) were collected 35 to 55 m below marine limit and are likely associated with younger and lower sea levels. Part of the early Holocene segment of the curve is derived from marine shells associated with washing limits. The early Holocene curve segment is based on 9 620 ± 90 BP (No. 23) and 9 610 ± 80 BP (No. 24) which provide ages for the 105-110 m and 100-105 m sea levels respectively. The youngest segment of the curve is based on *Mytilus edulis* dating to 5 660 ±110 BP (No. 20), from the surface of littoral deposits relating to sea level at 20 m a.s.l. It is believed this is the approximate area defining coastal regions experiencing submergence to the west and emergence to the east.

RICHARDSON BAY AREA

Glaciomarine deltas associated with an ice front dating to approximately 10 500 BP in the Richardson Bay area define marine limit at 160 m a.s.l. (Fig. III-3e). As in the west Bernard Harbour region, however, several radiocarbon dates cannot be used by themselves to define specific sea levels, and serve as minimum dates for deglaciation. These include shell samples 29, 32, 33 and 35 (Table III-3) which provide some of the oldest dates, but there is no field evidence to tie them to specific sea levels, although water depths of 7 m to 22 m can be estimated from Figure III-3e.

Wood collected from shallow sublittoral deposits at 23 m a.s.l. dates 6 100 ± 80 BP (No.

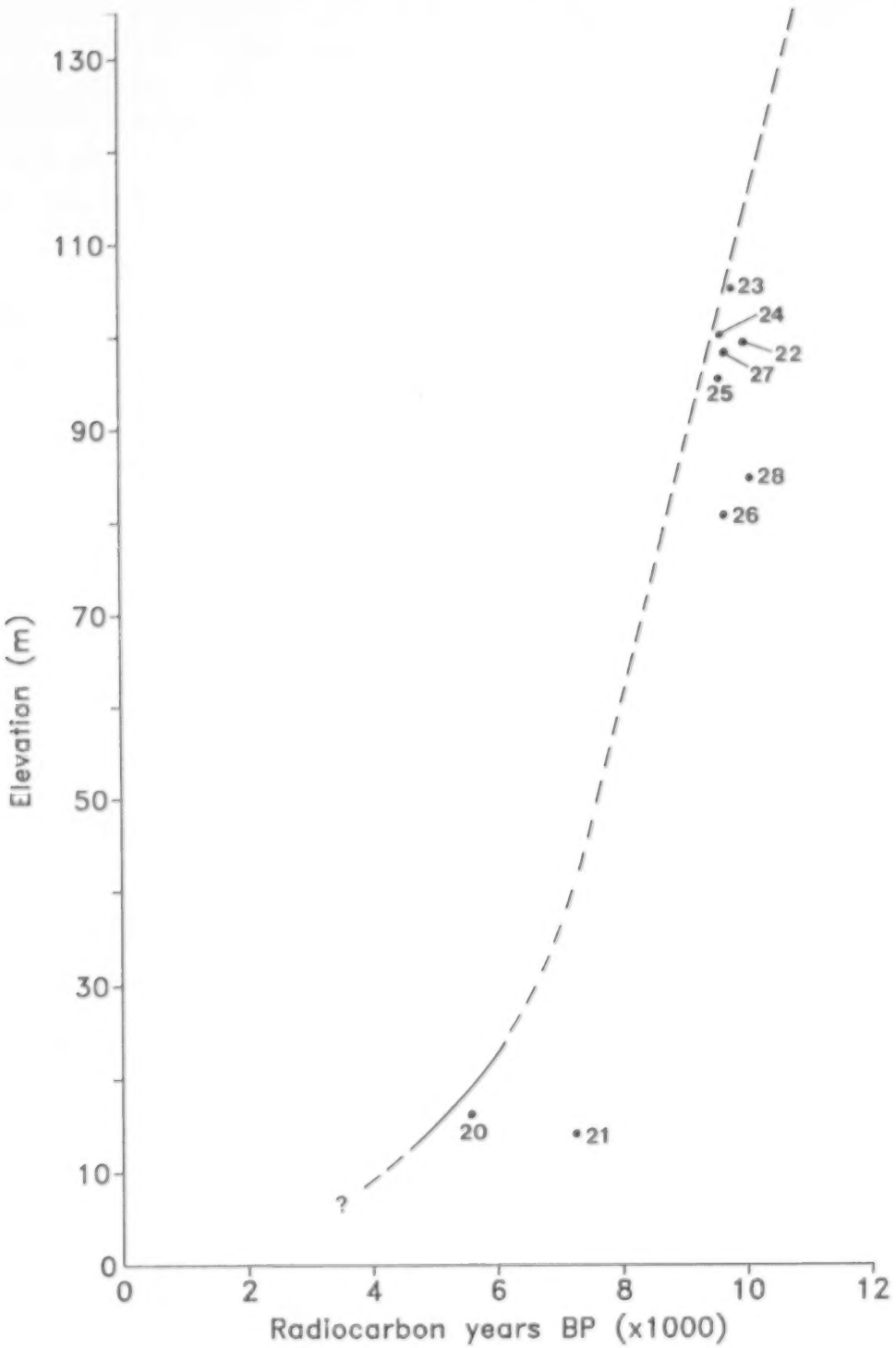

Figure III-3d: Relative sea level curve for the west Bernard Harbour area.

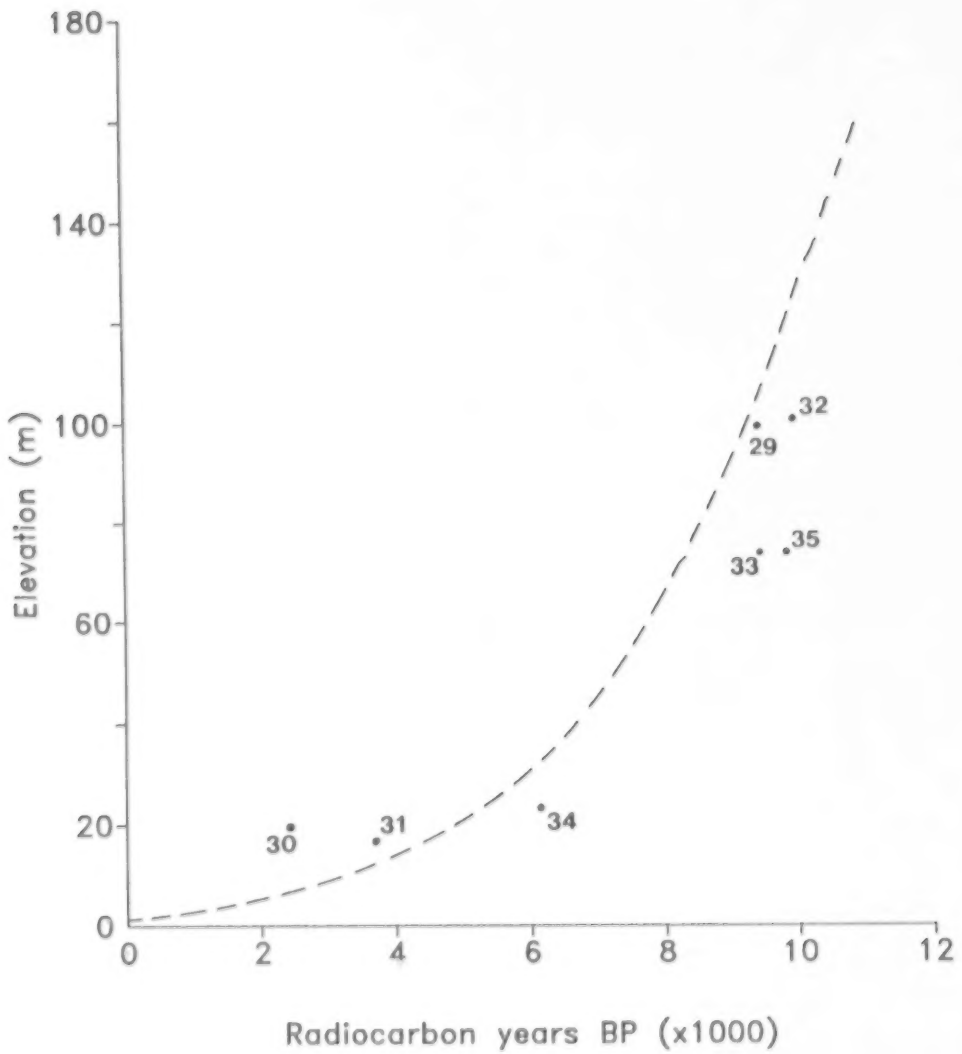

Figure III-3e: Relative sea level curve for the Richardson Bay area.

34, Table III-3) and provides a maximum age for a prominent shoreline at 25 m a.s.l. This date helps define the position of a younger segment of the emergence curve, as do terrestrial peat and wood dates (Nos. 30 and 31, respectively, Table III-3). The peat accumulating on a raised beach at 19 m a.s.l. indicates that sea level must have been below this elevation by 2.5 ka. It is unclear if the wood sample also collected from the surface of a beach at 16 m a.s.l. is associated with a sea level at this elevation.

NORTHERN BATHURST INLET

The Bathurst Inlet region is a larger area than previous sites and because of the longer period of local deglaciation, it has been subdivided here for sea level studies into north and south zones (Figs. III-3f, 3g). The period around 9 200-8 500 BP was marked by rapid deglaciation during which Bathurst Inlet became ice-free in less than 700 years. The sea transgressed as far as 150 km inland and up to 210 m a.s.l. in the north and 225 m a.s.l. in the south.

The oldest segment of the curve for the northern part on the inlet is defined by four dates and a marine limit of 210 m a.s.l., dated to about 9 200 BP. The oldest marine shells (Nos. 36 and 38, Table III-3) in the northern regions of the inlet date 9 190 ± 210 BP at 186 m a.s.l. and 9 170 ± 160 BP at 176 m a.s.l., respectively. These provide a minimum age for the local marine limit. A date of 8 070 ± 160 BP (No. 46, Table III-3) on the shallow water species *Mytilus edulis* from terrace gravels suggests a former sea level a few metres above the collection site at 152 m a.s.l. Seven other dates fall within the 8 700 to 7 500 BP period (Nos. 37, 41, 44, 45, 48, 49 and 50, Table III-3), but cannot be related to specific sea levels, as they are surface samples associated with fine-grained, deep water sediments. Similarly, Nos. 42, 43 and 47 (Table III-3) provide only a minimum estimate for sea levels in the middle Holocene. However, the lower and younger segment of the curve after this period has better control. Number 51 (Table III-3) is from plant detritus at 27.5 m a.s.l. occurring in foresets which are overlain by thin topset deposits whose surface is at 30 m a.s.l. This sample provides a maximum age for this paleosea level. Two more dates help bracket sea levels in the late Holocene. Number 40 (Table III-3) at 8 m a.s.l., is on shells found in sublittoral sediments associated with a sea level near 10 m a.s.l. The most recent date on *in situ* shallow water species *Mytilus edulis* (No. 52) at 5 m a.s.l. in sublittoral sediments is thought to be related to a sea level 2-4 m higher.

SOUTHERN BATHURST INLET

Although fewer radiocarbon dates exist for this part of the inlet, differences in emergence with the northern region are apparent. The older segment of the curve for southern Bathurst Inlet

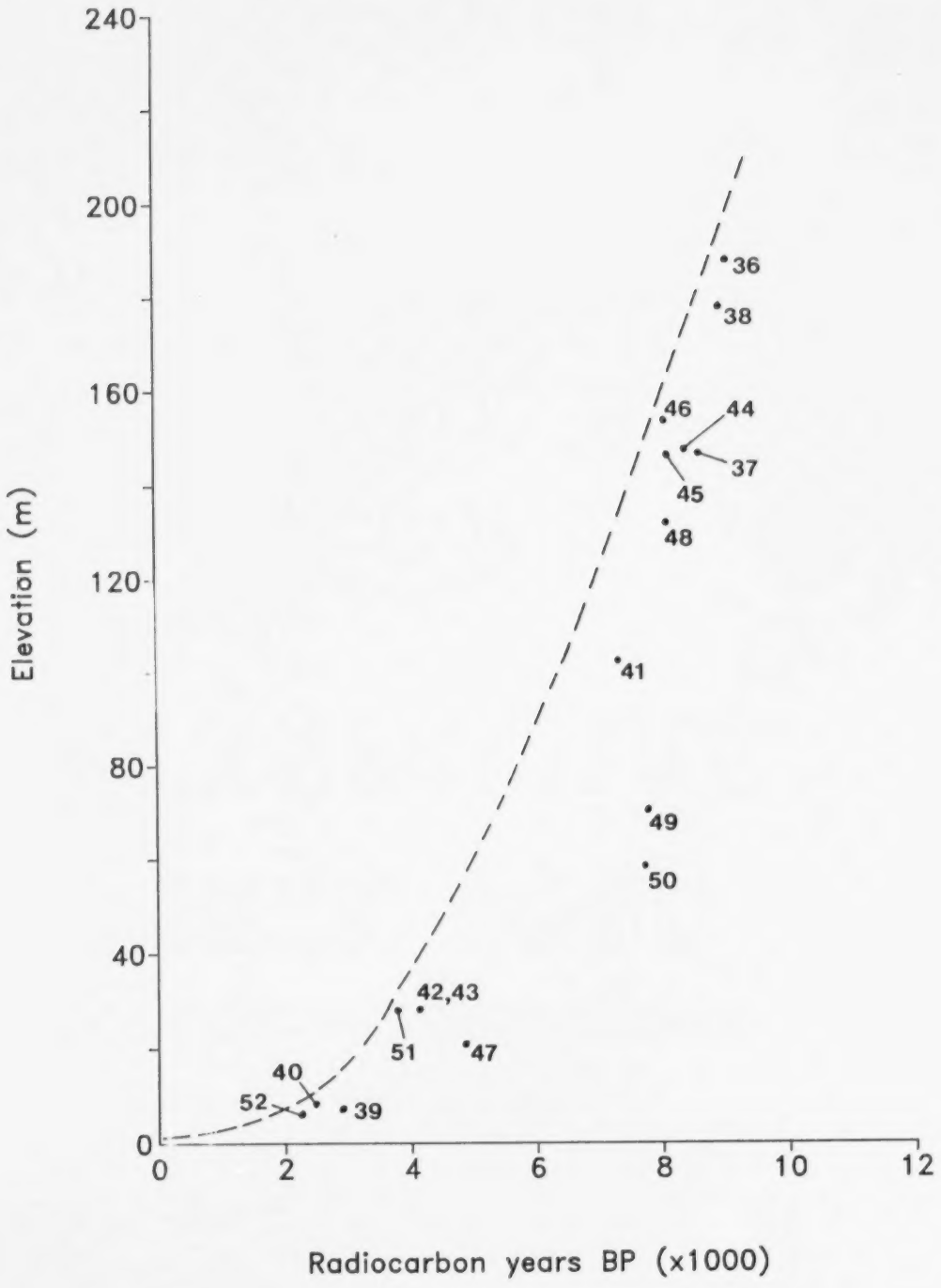

Figure III-3f: Relative sea level curve for northern Bathurst Inlet.

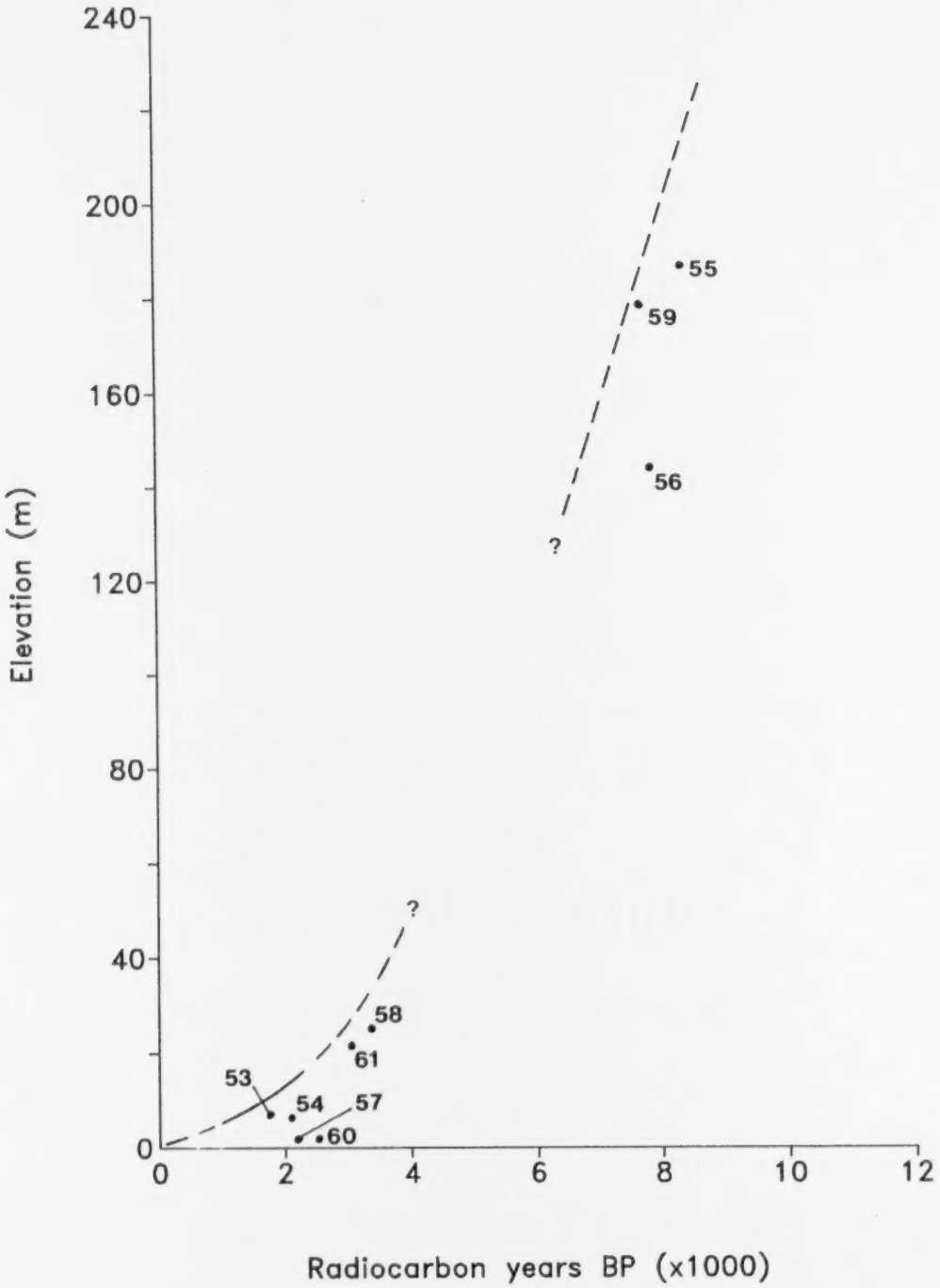

Figure III-3g: Relative sea level curve for southern Bathurst Inlet.

is extrapolated to deglaciation at 8.5 ka on the basis of adjacent regional deglaciation stages, as well as a marine limit inferred from glaciomarine deltas at 225 m a.s.l. Three shell samples help control the early Holocene segment of the curve (Fig. III-3g). Number 55 (Table III-3), at 186 m a.s.l., is associated with offshore sediments, and cannot be assigned to a specific sea level. Number 56, at 143 m a.s.l., is from the surface of a beach, and likely these shells predate its formation. Similarly, number 59 (Table III-3), also collected from a beach surface at 177 m a.s.l., likely relates to a higher sea level. The middle Holocene portion of the curve is not represented due to the absence of data for the period 7 600 to 3 600 BP. The lowermost and younger part of the curve is controlled by three radiocarbon dates. The first, based on *Salix* sp. at 23 m a.s.l., dates 3 490 ± 70 BP (No. 58, Table III-3) from the contact between bottomset and foreset sediments, and relates to a former sea level at 33 m a.s.l. (the delta surface). A second date on wood (No. 61, Table III-3) at 20 m a.s.l. in sandy foreset beds, is believed to be associated with a paleosea level at or near 29 m a.s.l., corresponding to the uppermost topset beds. A date of 1 850 ± 140 BP (No. 53, Table III-3) was obtained from *Mytilus edulis* which was *in situ* in bottomset sediments deposited when the sea was at or near 9 m a.s.l. which is the elevation of the delta top. Wood fragments dating 2 170 ± 140 BP (No. 54, Table III-3) at 5.8 m a.s.l., are from sublittoral sediments pertaining to a sea level higher than the collection site. Two additional dates on shells, Nos. 57 and 60 (Table III-3), serve only as minimum sea level indicators because they occur in fine-grained deep-water sediments.

These two curves from Bathurst Inlet suggest that postglacial emergence has been slightly slower in the north than to the south. This is in accordance with emergence curves represented here for areas further west along the mainland coastline.

DISCUSSION

Although no previously published sea level curves show evidence of forebulge influence in this part of the Arctic (Dyke and Dredge, 1989), the nesting of curves from Figure III-3a to 3g reflects the glacioisostatic response along a 1 000 km transect of increasingly greater loading. This transect includes sites from: a) an area just inside the limit of Laurentide ice (Paulatuk), b) sites well behind the ice limit (Clinton Pt., Clifton Pt., Bernard Harbour, Richardson Bay), and c) a site (Bathurst Inlet) closer to the centre of ice loading related to the M'Clintock Ice Divide (Dyke and Prest, 1987a). Marine limits are useful indicators to contrast increasing uplift along the transect from Paulatuk to Bathurst Inlet. They become progressively higher and younger, from 25 m a.s.l. at ca. 11.8 ka near Paulatuk to 225 m a.s.l. at 8.5 ka in southern Bathurst Inlet. Regional marine limit gradients have been estimated to be 0.28 m/km from Paulatuk to Clinton Pt., 0.36 m/km from Clinton Point to Clifton Point, and 0.27 m/km from Clifton Pt. to Bathurst Inlet.

The western region, from Paulatuk to Bernard Harbour, falls into Clark's (1978, 1980) Zone I/II transition, characterized by the collapse and migration of the forebulge. These sites experience emergence followed by progressively younger submergence in the form of rising sea level towards the east. The region east of Bernard Harbour through to Bathurst Inlet, falls within Clark's (1978, 1980) Zone I, characterized by continuous and ongoing postglacial emergence. Richardson Bay, for example, in close proximity to Coppermine, is experiencing emergence of about 3 m/1 ka (Andrews, 1989). The inflexion point marking the current transition for submergence/emergence may lie in the Bernard Harbour region. One interesting point is the apparent absence of dates on raised marine shells younger than 5.7 ka west of Bernard Harbour. These shells may exist above present sea level but have not yet been collected, or alternatively, they are presently below sea level because submergence likely initiated by middle Holocene or earlier.

In a regional overview, Andrews (1989) proposed that the boundary separating coasts that are still undergoing isostatic recovery from those that are submerging extends from northwest Victoria Island southwestward to approximately west of Clinton Point, although this boundary cannot be accurately mapped because of the lack of sufficient data. As noted by Sharpe (1992) for Wollaston Peninsula (Victoria Island) to the north, no submerged geomorphological features have been observed to support the theoretical interpretation of forebulge migration into these areas. However, additional surveys are required to test for the possible forebulge effects on Late Holocene sea level (D. Sharpe, pers. commun., 1994).

Emergence curves indicate a relatively rapid retreat of Laurentide ice responsible for crustal rebound similar to that which has occurred in other deglaciated Arctic regions. However, they do differ for example from the sea level record of Ellesmere Island (England, 1983) where initial emergence was relatively slow during retreat of Ellesmere ice. From Paulatuk to Bathurst Inlet, tilting of the marine limit resulted from the increased rates of emergence in the direction of the former centre of maximum glacial loading. Sea level curves derived from sites increasingly distant from the centre of the ice sheet (Bathurst Inlet to Paulatuk) appear to exhibit similar trends. Assuming a marine limit of 225 m a.s.l. and a date of deglaciation of 8.5 ka for the southern Bathurst Inlet area, about 23 percent of rebound (= 52 m) took place by 7.5 ka, and 50 percent of rebound by 6 ka.

Late Holocene emergence rates are necessarily highest closer to the centre of the former ice load. Blake's investigations (1963) of eastern Bathurst Inlet suggested a rate of 0.46 m per 100 years for the last 2 000 year period. An emergence curve established by Walcott (1972) for this same area is characterized by a decrease in sea level of about 100 m in the first 1 000 years, or approximately 10 m per 100 years as proposed by Dyke and Dredge (1989) for the first 1-2 ka period and decreasing to 0.66 m per 100 years at present (ibid). These values are higher than

those reported here for the same periods. For the last 2 000 years, emergence has been estimated at 0.25 m per 100 years in northern Bathurst Inlet and 0.5 m per 100 years for southern Bathurst Inlet, which is in close agreement with the preliminary work carried out by Blake. Low rates of emergence are reflected in the widespread occurrence of well-defined raised beaches along the present-day coastline of the central and eastern regions of the study area. Similar beaches at lower elevations are rare to absent in the west, possibly as a result of their submergence.

REGIONAL FRAMEWORK

To the west of the study area, submergence of coastal regions beyond the Late Wisconsin glacial limits (Clark's (1980) Zone II) has been reported from the Beaufort Sea coast by Hill *et al.*, (1985, 1993). There, a relative sea level curve for the continental shelf off Tuktoyaktuk Peninsula records a rise in sea level of approximately 140 m over the last 27 000 years. This has been attributed to ablation of the Wisconsin ice sheet, basin subsidence and sediment loading and compaction. From approximately 10-8 ka to 3 ka BP, a sea level rise of 7 to 14 mm/year has been reported (ibid), whereas this sea level rise has slowed considerably in the last 3 000 years to a probable maximum rate of 2.5 mm/year. The theoretical sea level curve derived from the Quinlan and Beaumont (1981) model and applied to the Beaufort Shelf, indicates a rise and fall of 20 m within the overall submergence cycle (Hill *et al.*, 1985). This has been attributed to the forebulge migration which causes a temporary fall in sea level between approximately 13 and 10 ka BP. The inferred segments of the observed sea level curve in which sea level falls between 15 and 12 ka BP, are generally consistent with the theoretical predictions (ibid).

On Banks Island (Vincent, 1983, 1984) and Wollaston Peninsula, southwestern Victoria Island (Sharpe, 1984, 1988, 1992), Late Wisconsin/Early Holocene marine features are attributed to ice retreat. Vincent(1983) presented a preliminary emergence curve for this period for the east coast of Banks Island. If sea levels assigned to these dates are correct, sea level was at 21 m a.s.l. by 11 200 BP, and had fallen to about 5 m a.s.l. by 9 600 BP. Andrews (1989) placed the Zone I/II transition near eastern Banks Island, and suggested the onset of continuous submergence around 6-4.5 ka BP. A sea level curve presented by Andrews (1989) for Banks Island exhibiting ongoing submergence is similar to the pattern for Paulatuk presented here, although neither accurately defines the onset of submergence.

Along the coast of Wollaston Peninsula on Victoria Island, marine limit was defined by Sharpe (1984,1988). On the western end of the peninsula, marine limit is approximately 110-115 m a.s.l., and dates at least 10 700 BP. However, few dates have been obtained on the marine limit on Victoria Island, and there are fewer glaciomarine deltas defining the marine limit than on the

mainland to the south. Two preliminary emergence curves for western and south-central Wollaston Peninsula show similarities for the early Holocene with sea level curves in the Clifton Pt. and west Bernard Harbour areas. Sharpe (1992) presented the Wollaston curves as direct exponential decay of glacioisostatic emergence. Both of his curves flatten rapidly below 30 m or for the last 8 000-9 000 years, suggesting continuing emergence throughout the Holocene, although, as in the present study, there are no dates on marine shells after 7 ka for reference. A detailed study with additional radiocarbon dates associated with marine sediments on Banks and Victoria islands is required to reconstruct the history of postglacial sea level history of the southwest Arctic archipelago.

Although no other sea level studies have been undertaken in present study area, postglacial emergence has received considerable attention east of Victoria Island. Dyke (1983) recognized that emergence curves on Somerset Island were different from those presently reported from other areas. Over 50 percent of total emergence had taken place within 1 000 years after deglaciation. Early emergence rates averaged 8 to 11 m per century, but reached as high as 30 m per century. This abnormally high rate was attributed to tectonically-induced changes in the landscape resulting from reactivation of the crust along preexisting faults. Further investigations by Dyke (1984) on Boothia Peninsula to the east, produced similar observations regarding emergence. During the early stages of deglaciation (9 400 to 9 700 BP), emergence rates on Boothia Peninsula and in regions south of the peninsula attained 30 m per century and 8 m per century respectively. These rates are considerably higher than those from the present study area, and are also greater than rates reported from any other regions of the Arctic. Dyke attributed these rates to either the concentration of the elastic portion of crustal rebound over a short interval or postglacial faulting. More recently, evidence for Holocene block tectonics was proposed by Dyke *et al.*, (1991) for the Somerset - Boothia - Prince of Wales region, in which postglacial rebound involved movement of a mosaic of crustal blocks.

Dyke *et al.*, (1991) also summarized the largest and most up-to-date collection of new and existing emergence curves for regions east of Bathurst Inlet, including Prince of Wales, Melville, Bathurst, Cornwallis, Devon and Somerset islands. Some of these emergence curves show overall patterns similar to those from the study area. An emergence curve based on early radiocarbon dates from Bathurst Inlet resembles a regional composite emergence curve based on a combination of new dates presented in this study as well as prexisting dates. On Melville Peninsula, Dredge (1990) also discussed changes in sea level based on five emergence curves over the last 9 000 years.

SUMMARY AND CONCLUSIONS

This study contributes to a better understanding of the role of the last continental glaciation in this region of the low Arctic, by bridging the mainland sea level record with that of the southwest Arctic islands, as well as relating a region of ongoing submergence to one currently experiencing emergence. The glacial history from Cape Parry to Bathurst Inlet records the rapid deglaciation of the coast occasioned by calving in a high sea level. The sea transgressed across a region recently deglaciated and depressed by glacioisostatic influence of the continental ice sheet. Marine limits were formed at the time of deglaciation (ranging from 11.8 to 8.5 ka) in areas behind the Late Wisconsin glacial limit.

Marine limits in the study area range from 10 m to 225 m a.s.l., which is the result of differential glacioisostatic uplift from west to east (Paulatuk to Bathurst Inlet) caused by increasing unloading towards the east. The study area has experienced initial rapid emergence and then progressively less emergence which has been replaced by submergence from Paulatuk to Bernard Harbour during the middle to late Holocene due to the eastward migration of the forebulge, whereas regions to the east continue to experience continuous emergence. The pattern and magnitude of observed postglacial sea level changes are in accord with theoretical predictions. In areas close to, but within the glacial limit, sea level initially falls during the early and middle Holocene, and then begins to rise due to the migration of the forebulge in late Holocene times. Submergence becomes progressively younger from west to east. Closer to the centre of ice loading, emergence has continued since deglaciation. The high marine limit above raised glaciomarine deposits suggests that, in response to the processes of glacial unloading, a high glacioisostatic sea level dominated over eustatic influence.

More accurate patterns of postglacial crustal recovery and ice-loading events may be revealed based on a greater number of well-controlled sea level curves from specific sites along the coast. Due to the limited number of control points, a greater concentration of late Holocene dates is required in order to define future trends in sea level change. Identification and interpretation of forebulge influence can only be resolved by further fieldwork at and beyond ice limits. Similarly, more detailed sea level studies of Banks and Victoria Islands should be considered before local sea level history can be related to that of the central Arctic.

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CHAPTER IV - LATE QUATERNARY PALEOECOLOGICAL SYNTHESIS OF MARINE FAUNA FROM THE POSTGLACIAL SEA, CAPE PARRY TO KENT PENINSULA, N.W.T.

INTRODUCTION

During the retreat of Laurentide Ice from Cape Parry to Perry River, Northwest Territories, marine waters flooded the isostatically depressed coastal lowlands south of Amundsen, Coronation and Queen Maud Gulfs (Fig. IV-1). The late-glacial sea created an extension of the Arctic Ocean about 12 000 to 13 000 BP in the Darnley Bay area (Fig. IV-1) and became progressively younger in the direction of ice retreat, i.e., south of Queen Maud Gulf, where it was established about 9 000 BP. Differential isostatic rebound, reflected in a marine limit which rises gradually west to east from about 10 m a.s.l. at Cape Parry to approximately 225 m a.s.l. in the Bathurst Inlet region, is responsible for the marine regression which has continued through to the present.

Invertebrate fauna are relatively common in postglacial marine sediments exposed along the coastal regions of the study area. This paper summarizes the results of a study of foraminifers, ostracodes and bivalve molluscs collected from sediments spanning the last 12 000 years. Its purpose is to demonstrate variations in microfossil diversity and abundance, lithological influences on fauna and interpret paleoenvironmental conditions. This is the first time detailed species lists of characteristic Late Quaternary microfauna have been provided for this part of the Arctic.

METHODS

Approximately 150 samples were collected from raised marine deposits in stratigraphic sections or on the surface. A total of 71 samples from 38 sites were fossiliferous (Fig. IV-1), the remaining being barren or containing only fossil fragments. Elevations, sediment type and age of samples are listed for the 71 sample localities in Table IV-1. About 100 g of dry sediment were washed through a 0.063 mm mesh wire sieve. The residues on the screens were then dried and examined for microfossils. Ostracodes and foraminifers were handpicked with the use of a binocular microscope and identified using published references.

The majority of foraminifers and ostracodes exhibited little or no abrasion, and ostracode valves were frequently paired. Sample size of the latter varied from 1 to 74 specimens, averaging 11 per locality. Foraminifera are generally more abundant, with samples ranging from 1 to 777 tests, with an average of 190 per site. Preservation of bivalve shells varied from site to site, but

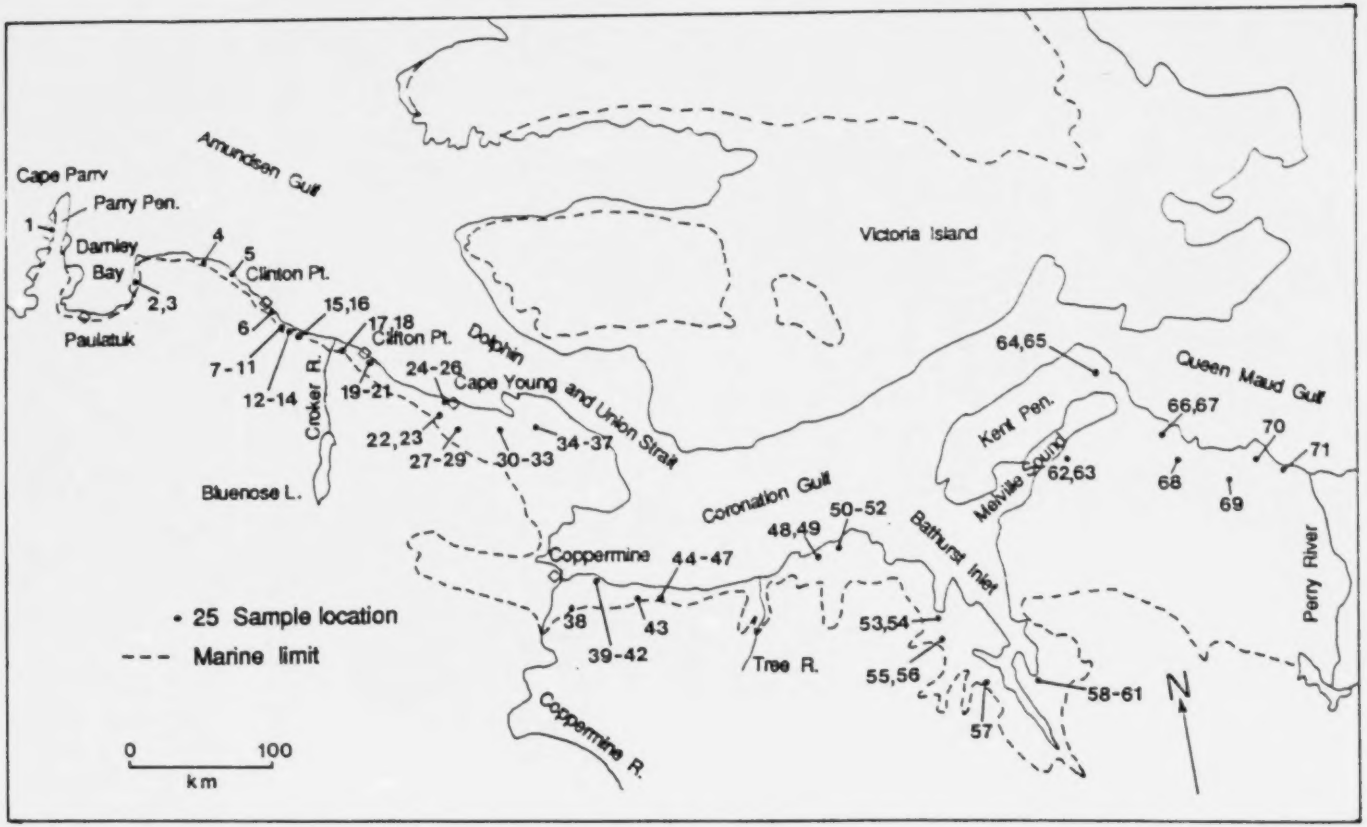

Figure IV-1: Location map of sample localities and regions inundated by submergence.

Table IV-1. Elevation, texture and age of samples.

Sample	Elevation (m)	Texture	Radiocarbon age (years BP)	Sample	Elevation (m)	Texture	Radiocarbon age (years BP)
1	2.5	sandy silt		37	17	sand	5 560 ± 120
2	5	sandy silt	11 790 ± 160	38	120	silty sand	
3	12	sandy silt		39	19	sand	
4	16.5	sandy silt	10 840 ± 180	40	17	sandy silt	
5	24	sand	10 340 ± 140	41	9	silty clay	
6	30	sand		42	5	silty clay	
7	27	silty clay	>10 620 ± 160	43	110	sand	9 080 ± 150
8	30	silty clay	10 620 ± 160	44	181	sand	
9	30	silty clay		45	178	sand	
10	25	sandy silt	10 000 ± 170	46	175	sandy silt	
11	13	silty clay	9 810 ± 120	47	173	sandy silt	
12	17	silty clay		48	26	silty sand	
13	29	sand		49	30	sand	
14	14	sandy clay	>10 600 ± 120	50	12	silty clay	>3 850 ± 210
15	32	sandy silt		51	24	sandy silt	>3 850 ± 210
16	36	sandy silt		52	27	sandy silt	3 850 ± 210
17	51	sandy silt		53	3	silty clay	
18	27	sandy clay		54	9	silty clay	
19	14	silty clay	8 890 ± 110	55	37	silty clay	
20	12	silty clay	>8 890 ± 110	56	42	silty clay	
21	10	silty clay	>8 890 ± 110	57	38	sandy silt	
22	69	silty clay		58	1	sandy silt	2 620 ± 110
23	74	silty sand		59	3	sandy silt	<2 620 ± 110
24	29	sand		60	6	sandy silt	<2 620 ± 110
25	27	sand		61	8	sandy silt	<2 620 ± 110
26	25	silty clay		62	1	silty sand	>2 330 ± 90
27	63	silty clay		63	4	silty sand	2 330 ± 90
28	68	silty clay		64	58	sandy silt	7 800 ± 150
29	71	silty clay		65	60	sand	<7 800 ± 150
30	16	silty clay		66	7	silty clay	
31	20	silty clay		67	12	silty sand	
32	23	sandy silt		68	25	silty clay	>5 170 ± 100
33	27	sand		69	21	silty clay	
34	4	silty clay	>5 560 ± 120	70	18	silty clay	
35	11	silty sand	>5 560 ± 120	71	4	silty clay	
36	15	silty sand	>5 560 ± 120				

paired valves, some with their periostracum preserved, were generally common, although single valves were predominant. In one locality, an intact mollusc with its siphon extended 2 cm was preserved in permafrost.

PREVIOUS STUDIES

In the study area, no systematic studies have been carried out on Late Quaternary micro and macrofossils from raised marine sediments. References to postglacial fossils consist predominantly of short species lists which form part of surficial geology investigations in regions of marine submergence (Bird, 1955; Blake, 1963). O'Neill (1924) examined postglacial Quaternary fossils from stratigraphic sections and surface collections along the Arctic coast, at a number of stations from the Yukon to Bathurst Inlet. These compilations provide information on macrofossils only. O'Neill concluded that fossils listed in his report belonged to species which formed part of the Western Arctic fauna.

Craig (1960), as part of a regional surficial geology mapping program, briefly discussed the distribution of seven Pleistocene pelecypod species and seven foraminifer species from 23 localities between Cape Young and the Tree River along the coast south of Dolphin and Union Strait, and Coronation Gulf. However, this was a preliminary study and no environmental interpretations were made from fossil distributions relating to the period of marine inundation. Kerr (1984) reported the existence of impoverished micro and macrofossil assemblages which characterized shallow Holocene estuarine environments in the Richardson River basin, west of Coppermine.

FORAMINIFERA

A total of 43 benthic foraminifera species and 1 planktonic species were identified from glaciomarine and postglacial marine sediments (Table IV-2); nine species are agglutinated and the remainder are calcareous. The distribution and relative abundance of the different species are listed in Tables IV-3 and IV-4, according to the geographic distribution of sample localities. Table IV-3 represents the Cape Parry - Clinton Point and Clinton Point - Coppermine coastal regions, whereas Table IV-4 refers to the Coppermine - Kent Peninsula coastal area. Five faunal assemblages have been defined for the Cape Parry - Kent Peninsula region, based on the different environments of deposition as indicated by textural, sedimentary and stratigraphic characteristics of the marine sediment samples. Recent water temperature, salinity and depth ranges of several species are presented in Table IV-5. Figure IV-2 illustrates the number of species versus the number of specimens for foraminifera from shallow and deep-water sample

Table IV-2. Foraminifera of the postglacial sea

Elphidium orbiculare (Brady)
E. clavatum Cushman
E. bartletti Cushman
E. williamsoni Haynes
E. incertum (Williamsoni)
E. subarcticum Cushman
Trochammina rotaliformis Wright
T. nana (Brady)
Spiroplectammina biformis (Parker and Jones)
Ammotium cassis (Parker)
Cornuspira involvens (Reuss)
Reophax scorpiurus Montfort
Psammosphaera fusca Schultze
Alveophragmium jeffreysi (Williamson)
Protochista findens (Parker)
Eggerella advena (Cushman)
Globigerina bulloides d'Orbigny
Buccella frigida (Cushman)
B. inusitata Andersen
Islandiella helenae Feyling-Hanssen and Buzas
I. norcrossi Cushman
I. inflata Gudina
Cassidulina crassa d'Orbigny
Robulus nikobarensis (Schwager)
Astrononion cf. *gallowayi* Loeblich and Tappan
Virgulina loeblichi Feyling-Hanssen
Dentalina ittai Loeblich and Tappan
D. frobisherensis Loeblich and Tappan
Triloculina trihedra Loeblich and Tappan
Pyrgo williamsoni (Silvestri)
Pateoris hauerinoides (Rhumbler)
Marginulina glabra d'Orbigny
Pseudopolymorphina novangliae (Cushman)
Laryngosigma sp.
Lagena gracillima (Seguenza)
L. semilineata Wright
Oolina apiopleura (Loeblich and Tappan)
O. caudigera (Wiesner)
O. acuticosta (Reuss)
O. melo d'Orbigny
Fissurina sp.
Quinqueloculina seminulum (Linne)
Q. stalkeri Loeblich and Tappan
Gordiospira arctica Cushman

Table IV-3. Distribution and abundance (%) of Foraminifera for the Cape Parry - Coppermine region

	C. Parry - Clinton Pt.					Clinton Pt. - Coppermine																																
	ASSEMBLAGE A					ASSEMBLAGE B																										ASSEMBLAGE C								
Sample localities	1	2	3	4	5	6	7	8	11	12	13	14	15	17	18	19	20	21	22	23	25	26	27	28	29	30	31	32	9	10	16	24	33	34	35	36	37
FORAMINIFERA																																						
Trochammina rotaliformis																12	2	2															3	8	2		
T. nana																5	3	4			3												<1	3			
Spiroplectammina biformis																<1		<1																			
Elphidium orbiculare			13	9		75	83	21	77		9		75	82	25	19	12	13	61	79	74	41		65	91	64	19	52	89	81	83	80	62	85	77	86	75
E. clavatum	94	96	78	75	100	13		11	5	100			12			4	9	8		15	13	2		3		8	6	6	11	18			38	9	7		
E. bartletti						4		5								23	34	33										1									
E. williamsoni			6	8		8												2								2		6									
E. incertum																								1													
Pseudopolymorphina novangliae	6	2	4			1		1			9		2			9	5	3		<1	3	1		1		2	6	7		<1		20		2	3		
Buccella frigida		1	1	8				20	10				4	16		10	27	24	3	2		3			3	2	13	2		<1	17			1	10		
B. inusitata																<1		<1																			
Quinqueloculina seminulum											37					1	<1					2				3									2		
Laryngosigma sp.													3		25	4	3	4		<1	3	2	6					4									
Fissurina sp.		1														<1						2				2							<1				
Islandiella helenae																3																					25
I. norcrossi																<1	<1					1															
Oolina melo																												<1						1			
O. apiopleura																<1																					
O. caudigera																				<1				1													
Cassidulina crassa								17	8					3	25	<1	4	4		<1		29		28	6	17	56	21									
Virgulina loeblichi								13								<1		<1				1						1									
Dentalina ittai																2		1																			
Triloculina trihedra						1		11	<1		46	99				<1			36		3	8	94	1													
Marginulina glabra												1																									
Lagena gracillima							17	1														8						<1									
L. semilineata															25	<1		<1																			
Gordiospira arctica																1																					
Globigerina bulloides																<1						1															
Cornuspira involvens																<1																					
No. of specimens	18	210	104	36	1	85	6	82	168	1	11	118	255	33	4	185	143	171	31	204	31	90	16	93	250	91	16	165	28	178	6	5	26	257	96	42	4
No. of species	2	4	5	4	1	6	2	9	5	1	4	2	6	3	4	24	11	16	3	7	6	13	2	7	3	8	5	11	2	4	2	2	2	6	7	4	2

Table IV-4. Distribution and abundance (%) of Foraminifera for the Coppermine - Kent Peninsula region

	ASSEMBLAGE D																ASSEMBLAGE E														
Sample localities	38	40	41	42	43	45	46	47	53	54	55	56	57	64	66	68	39	44	48	49	50	51	52	58	59	60	61	62	63	65	67	69
FORAMINIFERA																																
Trochammina rotaliformis														4														6			33	20
T. nana														2					33	80	4	50			13	20	12	6			33	40
Spiroplectammina biformis			<1											6					7	20												
Ammotium cassis															6				20		48							23	100			
Eggerella advena																												65				
Alveophragmium jeffreysi																														100		
Reophax scorpiurus															6						4											40
Psammosphaera fusca													<1								36											
Protochista findens														4																		
Cornuspira involvens																			33		8											
Elphidium orbiculare	68	71	70	25	86	83	90	91	23		33		98	74	19		39	66	7				100	100	85	80	88					
E. clavatum		3			3	16	7	5						4			50	23														
E. bartletti							<1	<1																								
E. williamsoni					1												12															
E. subarcticum				2			2																									
Quinqueloculina stalkeri															63	100						50									33	
Q. seminulum	6	1	2	12			<1						1																			
Astrononion cf. gallowayi																									2							
Pseudopolymorphina novangliae	<1			2	<1	<1	<1	1		100				2				12														
Buccella frigida					3	<1	<1	1																								
Laryngosigma sp.				<1	2	<1	<1	<1																								
Fissurina sp.				1				<1																								
Islandiella helenae				10																												
I. norcrossi				4					2																							
I. inflata													<1																			
Cassidulina crassa		17	2	17	3			1	65		40	50	<1																			
Oolina acuticosta														2																		
Robulus nikobarensis													<1																			
Virgulina loeblichi		1		26	2		<1	2					<1		6																	
Dentalina frobisherensis												50																				
Triloculina trihedra	20	5	24	1				<1																								
Pyrgo williamsoni	2	<1		<1							27																					
Pateoris hauerinoides		<1	1				<1																									
Lagena gracillima	3				<1			<1																								
No. of specimens	134	209	164	382	187	206	616	777	62	1	15	2	587	49	16	2	26	9	15	15	25	2	3	1	60	10	25	17	1	1	3	5
No. of species	6	8	6	12	9	5	8	11	6	1	3	2	7	8	5	1	4	3	5	2	5	2	1	1	4	2	3	4	1	1	3	3

Table IV-5: Summary of recent water temperatures, salinity and depth tolerated by some Late Quaternary Foraminifera of the postglacial sea.

Species	Depth (m)	Temperature (°C)	Salinity (ppt)
Trochammina nana	<200		
Spiroplectammina biformis	<66		
Ammotium cassis	2 to 6		
Cornuspira involvens	90 to 171		
Eggerella advena	<90		
Alveophragmium jeffreysi	<276		
Reophax scorpiurus	18 to 5 000		
Psammosphaera fusca	<171		
Elphidium ssp.	<71		<18 to >28
Elphidium orbiculare	<50		
E. clavatum	<20 to 375	4 to 5	34.5
E. williamsoni	55 to 200		
Buccella frigida	<43 to 400	- 2 to 5	<33 to 35
Quinqueloculina seminulum	18 to 458		
Q. stalkeri	45 to 387		
Islandiella helenae	13 to 230	- 2 to 4	31 to 34
I. norcrossi	<100 to 250		
Cassidulina crassa	50	3	33
Oolina apiopleura	<1592		
O. melo	153-458		
Robulus nikobarensis	<200 to >200		
Virgulina loeblichi	21 to 520	1 to 5	33 to 35
Dentalina ittai	<400	- 2 to 5	<35
D. frobisherensis	<520	1 to 5	33 to 35
Triloculina trihedra	200 to 3 000	4 to 5	34 to 35
Pyrgo williamsoni	<520	4 to 5	<35
Marginulina glabra	171 to 200		
Lagena gracillima	<200		
L. semilineata	<200	- 2 to 4	33 to 34

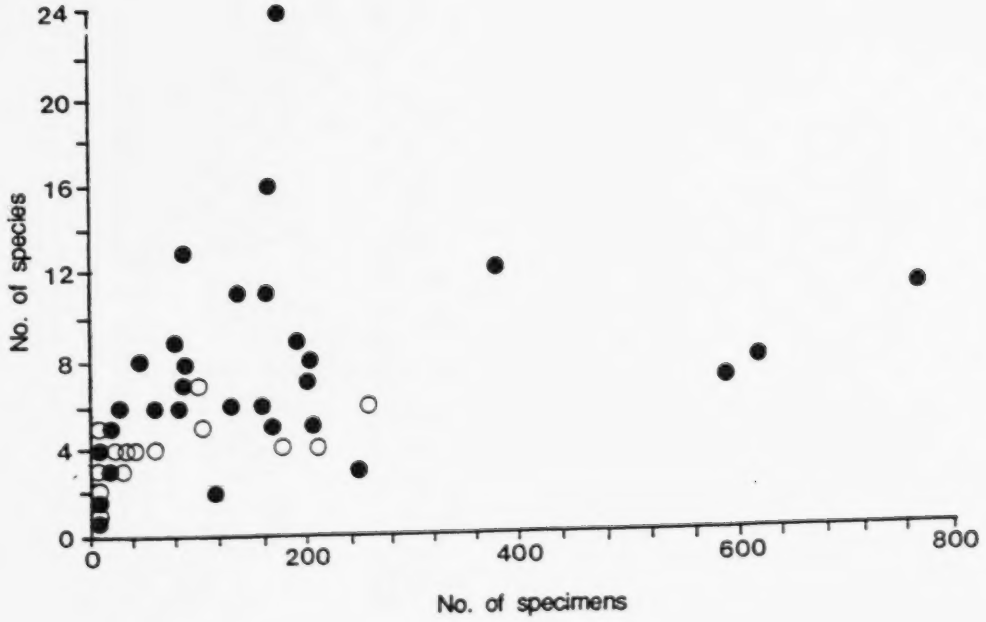

Figure IV-2: Number of foraminiferal species versus number of specimens for shallow (white dot) and deep-water (black dot) sample localities.

localities. The smallest sample size generally yielded fewer species. Species diversity and faunal abundance do not appear to be directly related, although samples from deep-water sediments are relatively more prolific.

ASSEMBLAGE A

Assemblage A, consisting of samples 1 to 5 from the Cape Parry - Clinton Point region, is poorly represented in the stratigraphic record. The sediments associated with this assemblage consist of massive to stratified sandy silt. Sediment samples are generally found near the base of a coarsening upward regressive sequence a few metres thick. Their elevations range from 2.5 m near Cape Parry where the marine limit is approximately 10 m, to 25 m a.s.l. west of Clinton Point where marine limit is 45 m. These stratigraphic data suggest a shallow sublittoral environment during the late-glacial to early postglacial marine phases during which water depths did not exceed 20 to 25 m. The Cape Parry - Clinton Point area was the first region to be deglaciated in the study area, and the earliest date on marine sediments is approximately 11 800 BP. The relatively small number of samples and variable foraminiferal abundance are difficult to interpret, but certain trends become apparent when sedimentary environment interpretations are considered.

The dominance of the genus *Elphidium* in this assemblage is of particular importance as Assemblage A comprises ubiquitous *Elphidium* species indicative of cold, shallow waters of low salinity (Cronin, 1976). As noted in Champlain Sea studies (Cronin, 1979), nearshore assemblages are dominated by various *Elphidium* species, suggesting that water was brackish and probably less than 30 m in depth. Similar observations were made by Bergen and O'Neil (1979), who stated that Alaskan fauna dominated by *Elphidium* species are found at depths of less than 30 m. The relatively shallow Arctic assemblage of the Chuckchi Sea living at depths of 6 m to 71 m (Cooper, 1964) is also dominated by species of the genus *Elphidium*. The shallow-water fauna along the Siberian coast described by Todd and Low (1966) is comparable to Assemblage A.

As noted in Table IV-2, *Elphidium* species comprise from 92 % to 100 % of the total fauna. This type of dominance by various *Elphidium* species is not uncommon and is known to occur in low diversity assemblages from Alaskan waters where the genus *Elphidium* encompasses 92 % of the fauna (Lagoe, 1979). *Elphidium clavatum* is typically restricted to relatively shallow, brackish waters such as estuarine and deltaic environments (Loeblich and Tappan, 1953; Anderson, 1963; Walton, 1964). It was also found to be characteristic of marginal marine conditions in the Gulf of St. Lawrence (Bartlett and Molinsky, 1972), where it usually inhabits water less than 10 to 20 m deep.

Elphidium orbiculare, recorded in Holocene glaciomarine deposits of Baffin Island (Feyling-Hanssen, 1976) and the Svalbard archipelago (Nagy, 1984), has commonly been found at depths of less than 50 m, both in the Chuckchi Sea (Cooper, 1964) and in Hudson Bay (Leslie, 1965). This species is also typical of shallow-water inshore fauna from the Canadian Arctic Archipelago (Vilks, 1969), as well as low diversity assemblages from shallow Alaskan waters (Lagoe, 1979). Although not as common as *Elphidium clavatum*, *E. williamsoni* has also been reported in modern waters of 55 to 200 m depth (Rodrigues and Hooper, 1982), as well as in Pleistocene sediments of shallower waters. Many *Elphidium* species, associated with shallow-water brackish conditions, can also tolerate salinities ranging from less than 18 ppt to greater than 28 ppt (Fillon and Hunt, 1974).

Buccella frigida, another typical shallow-water arctic species (Cooper, 1964; Vilks, 1969), is thought to signify depths ranging from 20 to 40 m in the Champlain Sea (Cronin, 1976). *Pseudopolymorphina novangliae*, also part of Assemblage A, has been reported in recent arctic and subarctic habitats, and as a rare constituent of Champlain Sea fauna (Cronin, 1977).

ASSEMBLAGES B AND D

Assemblages B and D, from the Clinton Pt. - Coppermine region and Coppermine - Kent Peninsula region respectively (Tables IV-3, IV-4), are well represented in the stratigraphic record. The sediments associated with these two assemblages generally consist of silty sand to silty clay. Sediment samples were collected from fine-grained deposits overlying glaciomarine diamictons and ice-proximal glaciomarine subaqueous outwash. Samples from both assemblages represent similar environments of deposition but from different geographic regions. Deposits from which samples were taken are also at the base of a regressive coarsening upward marine sequence which may attain ten's of metres in thickness. Approximate water depths are inferred from differences between sample elevation and local marine limit which rises from 40 m near Clinton Point, to over 200 m south of Kent Peninsula. Assemblages B and D are characterized by a high number of foraminifera specimens and similar species. In Assemblage B, the number of specimens in 23 localities ranges from 1 to 255, and the number of species, from 1 to 24, with an average of 98 specimens and 7 species. In Assemblage D, the number of specimens from 16 localities ranges from 1 to 777, and the number of species, from 1 to 12, with an average of 213 specimens and 6 species. Stratigraphic and sedimentologic evidence suggests that the deposits for both assemblages represent offshore environments in which deposition took place in comparatively deep water, approximately 50-75 m to 200 m depth. Distal glaciomarine environments and postglacial offshore conditions are recorded from about 11 000 BP in the west through to 8 000 BP in the east, reflecting progressively younger dates of deglaciation from west

to east. No fossils were observed in underlying glacial diamictons or subaqueous outwash sand and gravel.

Elphidium species contribute only moderately to these assemblages in comparison to Assemblage A (Tables IV-3, IV-4), and their relative abundance generally decreases as the number of species increases. *Elphidium orbiculare* is the dominant species, followed by *E. clavatum*. As noted above, the former is typical of shallow-water fauna from the Canadian western High Arctic (Vilks, 1969). Rodrigues and Hooper (1982) have also noted the presence of *E. clavatum* as a dominant species as deep as 375 m, in waters of 34.5 ppt with temperatures of 4 to 5°C.

The characteristic species of these assemblages consist of *Cassidulina crassa, Triloculina trihedra* and *Buccella frigida*, which is more dominant in Assemblage B, and *Virgulina loeblichi*, which is more abundant in Assemblage D (Tables IV-3, IV-4). An additional 24 different species are almost entirely restricted to these two assemblages. *Cassidulina crassa* has been reported as a typical species of Pleistocene glaciomarine fauna from northern Norway (Hald and Vorren, 1984), as well as from Holocene glaciomarine deposits of Svalbard archipelago (Nagy, 1984). Elverhoi *et al.*, (1980) noted its presence in Spitsbergen from an ice-proximal environment with a water depth of about 50 m. *C. crassa* has been found at various depths in the Gulf of St. Lawrence (Rodrigues and Hooper, 1982), as well as in Frobisher Bay where it is associated with silty clay and reflects the present arctic marine conditions (Dowdeswell *et al.*, 1985). Nagy (1984) noted that *C. crassa* is a dominant species where bottom-water salinity is approximately 33 ppt, and is also indicative of a bottom-water temperature of 3°C (C. Rodrigues, personal communication., 1985).

Another important constituent restricted to Assemblages B and D is *Triloculina trihedra* (Tables IV-3, IV-4). Cronin (1979) associated it with cold-water high-latitude environments. It has also been reported by Vilks (1969) between 297 and 457 m depth in the western High Arctic, and also between 200 and 400 m, in waters of 4 to 5°C, and 34 to 35 ppt in the Gulf of St. Lawrence (Rodrigues and Hooper, 1982). In addition, *T. trihedra* has been recorded by Markussen *et al.*, (1985) in cores at depths of 3000 m from the eastern Arctic Basin.

Buccella frigida is found in both Assemblages B and D, but occurs in greater number and more frequently in the former. It is referred to by Todd and Low (1967) as typical of cold water areas and has been recorded in marine Pleistocene deposits from Baffin Island (Feyling-Hanssen, 1976). It is today found in the Gulf of St. Lawrence between 55 m and 400 m depth, associated with salinities of less than 33 ppt to 35 ppt, and temperatures of -2 to 5°C (Rodrigues and Hooper, 1982). Wagner (1968) found the depth range of *B. frigida* variable in Hudson Bay, from 43 to 276 m, but was most abundant between 117 and 126 m.

Assemblage D, and to a lesser extent Assemblage B, are characterized by the presence of *Virgulina loeblichi*. This species reflects present arctic marine conditions in Frobisher Bay

(Dowdeswell *et al.*, 1985) where it is associated with silty clay of variable depth, but does not tolerate ice-proximal glacial conditions of lower salinity. Unlike the present study where *V. loeblichi* is associated with deep-water sediments (100-200 m), this species was reported to have a relatively shallow depth range of 21 to 64 m in Alaska (Loeblich and Tappan, 1953). However, Rodrigues and Hooper (1982) noted that although its depth range varied from 125 to 520 m, it was a dominant species at 390 m depth, associated with salinities of 33 to 35 ppt, and water temperatures of 1 to 5°C. Hald and Vorren, (1984) considered *V. loeblichi* to be a typical species of Pleistocene glaciomarine fauna in northern Norway.

A total of 18 other generally deep-water foraminifera species are found almost exclusively in Assemblages B and/or D (Tables IV-2, IV-3). One of these is *Islandiella helenae* which is considered to be essentially an Arctic species (Feyling-Hanssen and Buzas, 1976). It is regarded as a deep-water species and has been reported from a number of localities; it is present in Hudson Bay from 50 to 230 m depth (Leslie, 1965), in the Bering Sea in waters 100 to 200 m deep (Anderson, 1963), and from depths of 13 to 223 m off Alaska, Canada and Greenland (Loeblich and Tappan, 1953). *I. helenae* is also associated with silty clay of variable depth in Frobisher Bay, reflecting present marine conditions. Scourse *et al.*, (1990) reported this species at depths of 127 to 183 m, associated with proximal to distal glaciomarine sediments. Rodrigues and Hooper (1982) noted that it was a dominant species at 50 to 200 m depth in the Gulf of St. Lawrence, and was associated with salinities of 31 to 34 ppt, and water temperatures of -2 to 4°C.

Islandiella norcrossi, also restricted to a few sample localities in Assemblages B and D, is present in the Bering Sea from depths of 100 to 200 m (Anderson, 1963), and is also an abundant species in Hudson Bay at 100 m (Leslie, 1965), and a predominant species between 140 and 150 m (Wagner, 1968). Rodrigues and Hooper (1982) found *I. norcrossi* dominating at approximately 250 m depth in the Gulf of St. Lawrence, although its depth range was variable. This species was also recorded in Pleistocene marine deposits from Baffin Island (Feyling-Hanssen, 1976).

The genus *Lagena* is represented by *L. gracillima* (Assemblages B and D, Tables IV-3, IV-4) and *L. semilineata* (Assemblage B). Leslie (1965) found *L. gracillima* to be a dominant species around 100 m in Hudson Bay, whereas Vilks (1969) noted its occurrence below 200 m depth in the western high Arctic archipelago. It was reported from the Bering Sea by Anderson (1963) with a depth range of 100 to 200 m, although both *L. gracillima* and *L. semilineata* are found in Alaskan waters of less than 50 m (Loeblich and Tappan, 1953). The latter has also been found at variable depth, from 55 to 200 m in the Gulf of St. Lawrence with salinities of less than 33 ppt to 34 ppt, and temperatures ranging from -2 to 4°C.

Pyrgo williamsoni is restricted to 4 localities in Assemblage D (Table IV-4). It has been reported from glaciomarine sediments at depths of 127 to 183 m (Scourse *et al.*, 1990) and from

the Gulf of St. Lawrence between 400 and 520 m depth in waters of 34 to 35 ppt, and 4 to 5°C (Rodrigues and Hooper, 1982). It has also been noted by Dowdeswell *et al.*, (1985) from Frobisher Bay where it can tolerate existing ice-proximal glacial conditions of low salinity.

Two forms of the genus *Dentalina* are associated with Assemblage B, *D. ittai*, and Assemblage D, *D. frobisherensis*, although both species are relatively rare (Tables IV-3, IV-4). *D. ittai* has been reported from several high and mid-latitude regions at variable depths: 25 m in the Bering Sea (Anderson, 1963), from Alaska in less than 50 m (Loeblich and Tappan, 1953), 52 to 100 m in Hudson Bay (Leslie, 1965), and from 55 to 400 m depth in the Gulf of St. Lawrence, where salinities range from less than 33-35 ppt, and temperatures vary between -2 and 5°C (Rodrigues and Hooper, 1982). *D. frobisherensis* was also reported from 40 to 152 m depth in Hudson Bay (Leslie, 1965; Wagner, 1968), between 127 and 440 m in arctic waters (Scourse *et al.*, 1990; Vilks, 1969), and from between 125 and 520 m depth from the Gulf of St. Lawrence, associated with salinities of 33 to 35 ppt, and water temperatures of 1 to 5°C (Rodrigues and Hooper, 1982).

A number of species belonging to Assemblages B and/or D are found in only a few isolated localities (Tables IV-2, IV-3), and represent only a small percentage of the total fauna. Many have been reported as recent fauna from the Gulf of Alaska (Todd and Low, 1967), frequently associated with pebbly mud and occurring at variable depths: *Quinqueloculina seminulum*, common at 387 m and rare at 18 to 171 m; *Q. stalkeri*, rare from 45 to 387 m; *Cornuspira involvens*, rare from 90 to 171 m; *Robulus nikobarensis*, common between 171 and 200 m, and rare in shallower and deeper waters; *Margulina glabra*, rare between 171 and 200 m; *Oolina melo*, rare from 153 to 200 m; *Globigerina bulloides*, a planktonic species abundant from 153 to 200 m, common at 252 m and rare between 369 and 387 m. *Oolina melo* and *Quinqueloculina seminulum* have also been reported from the western Arctic Archipelago between 193 and 458 m, and below depths of 237 m respectively (Vilks, 1969).

Four additional species which are also restricted to Assemblages B and D include *Oolina acuticosta, O. apiopleura, Pateoris hauerinoides* and *Gordiospira arctica*. The latter, together with *P. hauerinoides* and *Oolina caudigera* have been reported from Alaska (Loeblich and Tappan, 1953), whereas *Oolina apiopleura* and *P. hauerinoides* have been found at depths of 1592 and 2653 m respectively from the west-central Arctic Ocean (Lagoe, 1977). The latter has also been reported from fine-grained glaciomarine sediments 160 to 180 m deep (Scourse *et al.*, 1990).

Several studies have shown that in arctic and subarctic regions, agglutinated species may contribute significantly to the shallow-water foraminifera population. A few sample localities within the relatively deep-water Assemblages B and D contain agglutinated foraminifera (Tables IV-3, IV-4), although they are not as common as in Assemblages C and E. For example, *Trochammina nana* has been documented by Vilks (1969) in the western High Arctic to be a ubiquitous species,

but is most common in waters less than 200 m deep. Similarly, *Reophax scorpiurus* occurs between 18 and 369 m depth in southern Alaska (Todd and Low, 1967) but up to 5 000 m in the north Atlantic and Pacific (Schröder *et al.*, 1988); *Psammosphaera fusca* has been found at a depth of 171 m (Todd and Low, 1967).

ASSEMBLAGES C AND E

Assemblages C and E, represented by sample localities from Clinton Pt. - Coppermine and Coppermine - Kent Peninsula respectively, represent similar environments of deposition, but in two different regions. The substrate associated with Assemblages C and E generally consists of sandy silt to silty sand. Sediment samples are generally from the upper part of a coarsening-upward marine off-lap sequence represented by deltaic foresets, topsets and bottomsets, tidal rhythmites and beach deposits. Inferred water-depths are derived from sample elevation and relative sea level position at the time of deposition. Geomorphic, stratigraphic and sedimentologic evidence of the sample localities is indicative of sublittoral to littoral environments in which water-depths are interpreted to be approximately less than 30-50 m. Assemblages C and E are well represented in the stratigraphic record and differ significantly from Assemblages B and D. The former are characterized by an important decrease in number of species and specimens in which Assemblage C averages 71 specimens and 3 species, and Assemblage E averages 14 specimens and 3 species.

These low diversity assemblages exhibit certain similarities with Assemblage A such as high concentrations of *Elphidium orbiculare* and *E. clavatum* (Tables IV-3, IV-4) which are usually indicative of cold, shallow environments. Another similarity with Assemblage A is the isolated occurrence of less common species which occur more frequently in Assemblages B and D: *Pseudopolymorphina novangliae, Quinqueloculina seminulum, Islandiella helenae* and *Buccella frigida*. The latter is a typical shallow-water species (Cooper, 1964; Vilks, 1969), and is thought to signify depths ranging from 20 to 40 m in the Champlain Sea (Cronin, 1976).

An important characteristic of Assemblages C and E is the significant increase in the relative abundance of agglutinated species, as well as their greater geographic distribution over previous assemblages (Tables IV-3, IV-4). In the Canadian Arctic, Vilks (1969) and Lagoe (1977) found that shallow water faunas are dominated by agglutinated foraminifera. This was also noted from the Eastern Siberian Coast (Todd and Low, 1966), where the fauna consists chiefly of arenaceous forms, associated with waters 10 to 55 m deep. Agglutinated species are relatively common in Hudson Bay (Leslie, 1965), as well as in the Bering Sea (Anderson, 1963) in which arenaceous forms comprise 75 to 100 % of the fauna between approximately 20 to 100 m depth. Hooper (1975) noted that agglutinated foraminifera of the St. Lawrence estuary are characteristic

of shallow waters with temperatures of -1 to 8°C, and salinities of 21 to 32 ppt. MacLean *et al.*, (1989) found that in the mid to high Arctic, agglutinated species presently dominate the sediments in water depths shallower than 200 m. The distribution of agglutinated foraminifera in Assemblages C and E is typical of shallow-water environments of the Arctic. *Trochammina nana* has been reported in waters 1 to 6 m deep off northeast Alaska (Lagoe, 1979), and Loeblich and Tappan (1953) noted the presence of *T. rotaliformis* in Alaskan waters. MacLean *et al.*, (1989) found that *Spiroplectammina biformis* is less common in Arctic waters than *T. nana*, which is also the case in the present study (Tables IV-3, IV-4). The former has been recorded in waters 1 m deep in northern Alaska (Lagoe, 1979), 45 m deep in southern Alaska (Todd and Low, 1967), and in waters less than 66 m deep in the western High Arctic (Vilks, 1969). *Ammotium cassis* was found at depths of 2 to 6 m from northern Alaska (Lagoe, 1979), whereas *Eggerella advena*, present in shallow waters of the western High Arctic (Vilks, 1969), was noted by Todd and Low (1967) in Alaskan waters of 18 to 90 m depth.

Vilks (1969) found *Alveophragmium jeffreysi* in the upper 200 m of the western High Arctic archipelago, and Wagner (1968) identified it as a dominant species in samples from 199 m depth in Hudson Bay, although it is present in waters 43 to 276 m deep. *Reophax scorpiurus* also appears to have a variable range in depth, as it is found in Alaskan waters of less than 50 m deep, as well as in Hudson Bay, where it ranges from 43 to 276 m, becoming dominant at 117 m depth. Thus, the presence of certain agglutinated foraminifera in the deeper-water Assemblages B and D is not unexpected.

DISCUSSION

Although the possibility of transport and redeposition of foraminifera is present, it is difficult to estimate the importance of this process. Mixing of fauna could have occurred, notably in the latter stages of sedimentation when erosion of previously deposited marine sediments could take place by downcutting of rivers. However, reworking of the sediments seems to have played a minor role, as resedimentation should lead to random distribution of the microfauna, but this does not occur.

The nature of the substrate has been considered by some as probably the most important factor in the distribution of foraminifera (Loeblich and Tappan, 1953; Wagner, 1968). Inasmuch as the foraminifera appear to be related to bottom sediment, i.e., shallow-water fauna in silty sand of Assemblages A, C and E, and the deeper-water fauna in the sandy silt and clay of Assemblages B and D, salinity may be a more limiting factor of distribution. It is the ability of the genus *Elphidium* to tolerate brackish-water and harsh, rapidly fluctuating environmental conditions which permits it to dominate near-shore zones. Species such as *Pyrgo williamsoni, Triloculina trihedra, Buccella*

frigida and *Virgulina loeblichi* which require stable, more saline environments, are likely to be found at greater depths where favorable, near-normal marine conditions exist. It is believed that the relationship between fauna and sediments reflects the stratigraphic position of the foraminifera within a regressive marine sequence. Shallow marginal marine conditions are commonly associated in the study area with relatively high energy, coarse-grained sediments, whereas near-normal marine conditions are related to a deeper low energy zone with a fine-grained substrate. The depths at which species most commonly occur may thus be related to different salinity concentrations in the water column (Table IV-6).

No significant geographical influence on the number of species and specimens is evident from the study area, although minor differences in abundance do exist. The average number of specimens in Assemblages C is considerably higher than its equivalent (Assemblage E) further east. Conversely, Assemblage B has noticeably fewer specimens than Assemblage D to the east. The average number of species, however, is almost identical for Assemblages B and D (6 and 7 respectively) and for Assemblages C and E (3 in both cases). The reason for these minor differences is not known.

OSTRACODA

Temperature and salinity-sensitive ostracode species provide a useful tool for inferring environmental changes during the history of marine inundation from Cape Parry to Kent Peninsula. Although ostracodes are not as common as foraminifera, they generally can provide a greater potential for indicating paleoenvironmental conditions because of distinct freshwater, brackish water and marine species. The number of microfossils recovered is highly variable, and consequently the number of species also varies. A total of 16 ostracode species were recorded from the same sediment samples as foraminifers (Table IV-7). Two of the ostracode species are of freshwater origin, 4 are brackish water species and the remainder represent marine forms.

Ostracodes have been used to define 5 environmental phases of the postglacial sea (Table IV-8). As with the foraminifera, assemblages have been defined on the basis of ostracode distribution within different sedimentary environments. Assemblage 1 corresponds to foraminiferal Assemblage A , whereas Assemblages 2 and 4 correspond to Assemblages B and D, and Assemblages 3 and 5 to C and E respectively. Recent water temperature, salinity and depth ranges of some ostracode species are listed in Table IV-9. Figure IV-3 illustrates the number of species versus the number of specimens for Ostracoda for shallow and deep-water sample localities. In this case, the number of species generally increases as the number of specimens increase. This distribution also suggests that Arctic ostracode assemblages show increased diversity with depth.

Table IV-6. Inferred ranges of potential paleoenvironmental conditions for foraminiferal assemblages.

Assemblages	Depth (m)	Temperature (°C)	Salinity (ppt)
A	<20 to 25	- 2 to 5	<18 to 34
B, D	50 to 200	1 to 4	33 to 34
C, E	<30 to 50	4 to 5	<18 to 34

Table IV-7. Ostracoda of the postglacial sea

Eucitheridea bradii (Norman)
E. macrolaminata (Elofson)
E. punctillata (Brady)
Cytheropteron montrosiense Brady, Crosskey & Robertson
C. paralatissimum Swain
Leptocythere sp.
Loxochoncha venepidermoidea Swain
Paracyprideis pseudopunctillata Swain
Cytheromorpha macchesneyi (Brady and Crosskey)
Heterocyprideis sorbyana (Jones)
Pseudocythereis simpsonensis Swain
Acanthocythereis dunelmensis (Norman)
Candona cf. *lactea* Baird
Potamocypris cf. *pellucidus* Swain
Argilloecia conoidea Sars
Ilyocypris gibba (Ramdohr)

Table IV-8. Distribution and abundance (%) of Ostracoda for the Cape Parry - Bathurst Inlet region.

	C. Parry-Clinton Pt.				Clinton Pt. - Coppermine																				Coppermine - Kent Peninsula										
	ASSEMBLAGE 1				ASSEMBLAGE 2																ASSEMBLAGE 3						ASSEMBLAGE 4								ASSEMBLAGE 5		
Sample localities	1	2	3	4	6	7	8	15	19	20	21	22	23	25	26	28	29	30	31	32	24	33	34	35	36	37	40	41	42	43	45	46	53	55	39	51	60
OSTRACODA																																					
Pseudocythereis simpsonensis									32	24	29	50		20	11	100		25	83	42		50					27			47		33				67	100
Eucitheridea bradii			16	50					5	8	11		62	60	20						100	50	20	15	50	25		14										
E. macrolaminata									30	42	30		13		63		80	75		12				25	13		27	72		3							
E. punctillata									9	11																				5							
Cytheropteron montrosiense	100	100	33			100	100	89					25														27	14	22		100	67	100	100			
C. paralatissimum					8							50														25											
Heterocyprideis sorbyana					54																														50		
Paracyprideis pseudopunctillata									18						6		20							10											50		
Potamocypris cf. pellucidus								11																												33	
Argilloecia conoidea																							60	10													
Leptocythere sp.									6	5	4																										
Loxoconcha venepidermoidea									2	3	7			20					4	9							10										
Cytheromorpha macchesneyi			51	50	39					8	22								13	36			20	40	37	50				45							
Acanthocythereis dunelmensis																													78								
Candona cf. lactea																											9										
No. of specimens	8	2	12	2	13	1	1	9	44	38	27	2	8	5	35	6	5	4	23	33	1	2	5	20	8	4	11	7	9	74	2	3	5	1	2	3	1
No. of species	1	1	3	2	3	1	1	2	7	7	6	2	4	3	4	1	2	2	3	4	1	2	3	5	3	3	5	3	2	4	1	2	1	1	2	2	1

Table IV-9: Summary of recent water temperatures, salinity and depth tolerated by some Late Quaternary Ostracoda of the postglacial sea.

Species	Depth (m)	Temperature (°C)	Salinity (ppt)
Eucytheridea bradii	5 to 750	0 to 20	10 to 35
Cytheromorpha macchesneyi		0 to 12	
Cytheropteron sp.			29 to 35
Acanthocythereis dunelmensis		0 to 12	32 to 35
Eucytheridea punctillata	5 to 435	0 to 20	10 to 35
E. macrolaminata		- 2 to 10	
Heterocyprideis sorbyana	<1 400	- 2 to 18	2 to 35
Argilloecia conoidea	<1 000		

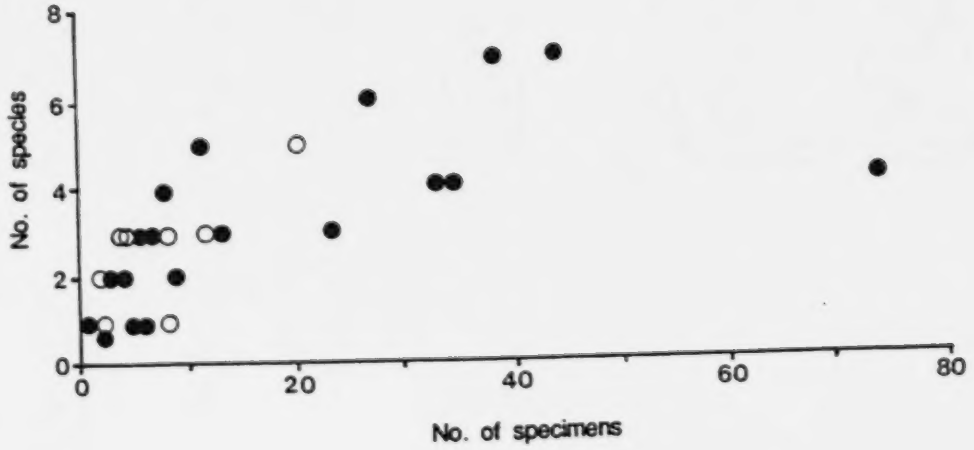

Figure IV-3: Number of ostracode species versus number of specimens for shallow (white dot) and deep-water (black dot) sample localities.

ASSEMBLAGE 1

Assemblage 1, consisting of samples 1 to 4 from Cape Parry to Clinton Point, is poorly represented due to the relatively small number of samples and specimens. As discussed above (Assemblage A), the sediment samples reflect an early, shallow (<25 m) sublittoral marine environment. Assemblage 1 is associated with only 3 species (Table IV-8). *Eucytheridea bradii* is generally considered to be a brackish water species which can tolerate salinities from 10 to 35 ppt, and is abundant in sandy Champlain Sea deposits (Cronin, 1977a). Its annual temperature range is from 0 to 20°C, and has been found at depths varying from 5 to 750 m (Hazel, 1970). It has also been recorded in the Barents Sea by Neale and Howe (1975).

Swain (1963) considered *Cytheropteron montrosiense* to be a marine species from Pleistocene near-shore marine sediments from the Arctic Coastal Plain of northern Alaska. It has also been reported in Late Wisconsin glaciomarine sediments at depths of 140 to 180 m, although it is not known as a living species anywhere today (Scourse *et al.*, 1990). *Cytheromorpha macchesneyi* is the third member of Assemblage 1 and has previously been reported from the Barents Sea and in Champlain Sea sediments. Cronin (1981) reported an annual temperature range of 0 to 12°C for this species.

ASSEMBLAGES 2 AND 4

Assemblages 2 and 4, from the Cape Parry - Coppermine region and Coppermine - Kent Peninsula region respectively (Table IV-7) are relatively well represented in the stratigraphic record. As with foraminiferal Assemblages B and D, Assemblages 2 and 4 are both associated with relatively deep-water environments of the early postglacial sea. In Assemblage 2, the number of specimens in 16 localities ranges from 1 to 44, and the number of species, from 1 to 7, with an average of 16 specimens and 3 species. In Assemblage 4, the number of specimens from localities ranges from 1 to 74, and the number of species, from 1 to 5, with an average of 14 specimens and 2 species.

Assemblages 2 and 4 are characterized by the presence of several marine species as well as the ubiquitous *Eucytheridea* species which are more tolerant of a wide range of salinities. *Pseudocythereis simpsonensis*, occurring in several samples (Table IV-8), was first recorded by Swain (1963) from Pleistocene marine deposits along the Arctic Coastal Plain of northern Alaska and is considered to be a marine species. *Paracyprideis pseudopunctillata, Loxoconcha venepidermoidea* and *Cytheropteron paralatissimum* are all marine species (Swain, 1963), but their environmental significance is difficult to ascertain. *C. paralatissimum* has also been reported in circumpolar glaciomarine sediments from Greenland, the Barents Sea and in Champlain Sea

deposits. Brasier (1983) noted that *Cytheropteron* species are deeper-water ostracodes found particularly on fine-grained substrates, in environments with salinities of 29-35 ppt (Cronin, 1977a). *Acanthocythereis dunelmensis*, although relatively rare (Table IV-8), is a marine species indicative of salinities of approximately 32-35 ppt and temperatures of 0-12°C (Elofson, 1941; Cronin, 1977b). As in Assemblage 1, *Cytheropteron montrosiense* is also an important marine constituent of Assemblages 2 and 4.

The genus *Eucytheridea* is a common member of many samples in Assemblages 2 and 4. *E. punctillata* is considered to be a brackish water species which tolerates salinities of 10 to 35 ppt, and is abundant in Champlain Sea sediments. Its annual temperature range is from 0 to 20°C, and has a depth range of 5 to 435 m (Hazel, 1970) in the western Atlantic. A second species, *E. macrolaminata*, generally lives in frigid climatic zones, and is known to live off the coast of Greenland and Norway where temperatures range from -2 to 10°C (Elofson, 1941). *E. bradii* is associated with glaciomarine sediments deposited at depths of 130 to 180 m (Scourse *et al.*, 1990).

The presence of 2 freshwater ostracode species found in Assemblages 2 and 4 is also of interest. *Potamocypris pellucidus* and *Candona lactea* have been reported in Late Pleistocene deposits from the Arctic Coastal Plain of northern Alaska and suggest that transport and mixing of freshwater and marine faunas by rivers was taking place at least locally.

ASSEMBLAGES 3 AND 5

Assemblages 3 and 5, represented by sample localities from Clinton Point - Coppermine and Coppermine - Kent Peninsula respectively, are not well-defined in the stratigraphic record. As previously discussed under Assemblages C and E, Assemblages 3 and 5 are interpreted as representing near-shore sublittoral depositional environments which are characterized by a combination of marine, brackish and freshwater ostracode species. These assemblages exhibit a significant decrease in both number of specimens and sample localities. Assemblage 3 consists of 6 samples, averaging 6 specimens and 3 species, whereas Assemblage 5 consists of only 3 samples with an average of 2 specimens and 2 species.

As with their corresponding foraminiferal assemblages (C and E), a large proportion of samples from Assemblages 3 and 5 yielded small numbers of ostracode specimens, generally less than 5, and most had relatively low numbers of species, up to 5 at locality 35. The sparseness of the fauna permits only preliminary paleoenvironmental interpretations at this time. The brackish-tolerant species *Eucytheridea bradii* and *E. macrolaminata* suggest that salinities and water temperatures may have varied from 10 to 35 ppt and 0 to 10°C. *Heterocyprideis sorbyana*, occurring in only one sample from Assemblage 5 (Table IV-8), can tolerate salinities ranging from 2

to 35 ppt and temperatures from -2 to 18°C (Neale, 1963). It has been reported at depths of up to 1400 m off the Newfoundland coast is associated with different substrates (Benson *et al.*, 1983). The presence of *Argilloecia conoidea* is difficult to interpret as it is also found in Newfoundland waters up to 1000 m deep.

DISCUSSION

Despite the large salinity tolerance range (10 to 35 ppt) of certain ostracode species in Assemblages 2 and 4, it is possible that the relatively deep-water environments (50 to 200 m) associated with these two assemblages represented comparatively stable marine conditions with salinities of approximately 32-35 ppt (Table IV-10). They represent the oldest postglacial marine environments, with the exception of certain samples from Assemblage 1, related to areas of greatest isostatic depression.

As the sea gradually regressed to lower elevations due to emergence, marine environments became progressively shallower and were under a greater coastal/terrestrial influence. The mixed associations of marine, brackish and freshwater ostracodes suggest periods of fluctuating salinities, affected by an increasing influence of freshwater run-off in a progressively shallowing sublittoral environment. The influx of freshwater from ancestral present-day rivers draining the coastal lowlands are likely a factor resulting in the low diversity ostracode assemblages noted in this study. Low diversity faunas from parts of the Beaufort Sea have also been attributed to reduced salinities caused by discharge of the Mackenzie River (Briggs, 1980). Low species diversity assemblages dominated by *Eucytheridea* and *Heterocyprideis* are characteristic of brackish waters of estuaries and near-shore conditions.

Throughout the marine episode, water temperatures did not exceed 10°C. Although some species present have the ability to live in warmer waters, this upper temperature limit is defined by the presence of *Eucytheridea macrolaminata* and *Cytheromorpha macchesneyi*. No apparent geographical variations were noted in the study area, and the nature of the substrate does not appear to have been a major effect on ostracode distribution. Pokorny (1978), however, noted that coarse-grained sediments contained small ostracode populations, whereas heterogeneous sediments supported a larger, more diversified fauna.

BIVALVE MOLLUSCS

The first collections of molluscs from Canadian Arctic waters were made in the nineteenth century, and consequently, as opposed to microfossils, macrofossil collections were established relatively early. O'Neill (1924) noted the occurrence of several living species of marine bivalves

Table IV-10. Inferred ranges of potential paleoenvironmental conditons for ostracode assemblages.

Assemblages	Depth (m)	Temperature (°C)	Salinity (ppt)
1	<20 to 25	0 to 10	10 to 35
2, 4	50 to 200	0 to 10	32 to 35
3, 5	30 to 50	0 to 10	10 to 35

along the coast of Dolphin and Union Strait. His findings show a greater number of species than does the present collection from Late Pleistocene and Holocene raised marine deposits within the study area. Fossils listed in Table IV-11 represent an impoverished bivalve fauna, representing 13 species. Although there is no clear faunal succession apparent in Table IV-12, bivalve distribution illustrates certain stratigraphic and geomorphic differences between the various sample localities and microfauna assemblages. Recent water temperatures, salinity and depth ranges of some mollusc species are listed in Table IV-13.

The most common bivalve species is *Hiatella arctica* which occurs in raised marine deep-water silty clay sediments to littoral sandy sediments from Cape Parry to Kent Peninsula (Table IV-12). Living counterparts of this species have been reported from a wide range of water depths: 35 to 165 m in Hudson Bay, being most abundant between 35 and 60 m depth, and 50 to 60 m off Greenland (Ockelman, 1958). This species is also associated with sand and muddy sand from shallow water deposits of the Champlain Sea and tolerates salinities of 20 to 32 ppt (Rodrigues and Richard, 1983, 1985). It is currently distributed throughout the study area and many regions of the Arctic, including Frobisher Bay, where it is associated with ice-distal waters of 0°C, 32 ppt at depths of 5 to 250 m (Aitken, 1990). Fossil localities are numerous from Cape Parry to Kent Peninsula. This species is also associated with all deep-water assemblages (Table IV-12).

The second most widespread bivalve is *Macoma balthica*. This is a ubiquitous species which can tolerate a wide range of salinities and temperatures. This ability provides it with a considerable advantage over other species, enabling it to populate less hospitable environments. *M. balthica* is also adapted to both coarse-grained substrates of the littoral zone and muddy deposits of offshore environments, which explains its widespread distribution. It is common in intertidal and shallow subtidal environments of the Canadian Arctic down to 20 m (Lubinsky, 1980), but has also been found living in waters as deep as 276 m (Wagner, 1968; Stanley, 1970). This variable depth range is accompanied by a high tolerance of fluctuating salinities, from 4 to 35 ppt (Hillaire-Marcel, 1980). However, the pelagic larvae of *M. balthica* require a minimum temperature of 10°C to survive (Lammens, 1967), suggesting that some shallow marine waters attained temperatures of 10°C at least for a short period of time during the summer. Within the study area, fossils are found in both shallow and deep-water sediments, from Clifton Pt. to Bathurst Inlet (Table IV-12).

Another common, typically arctic species is *Macoma calcarea* which is also found in a number of deep and shallow-water samples from a wide area (Table IV-12). It is widespread in the Arctic and has been recorded living in waters 5 to 560 m deep in Frobisher Bay (Aitken, 1990) and 76 to 276 m deep from Hudson Bay, but was found to be most abundant at the shallower depth range. This species lives in waters which do not exceed 0°C and whose salinities are greater than

Table IV-11. Bivalve molluscs of the postglacial sea

Hiatella arctica (Linné)
Macoma balthica (Linné)
M. calcarea (Gmelin)
Mya truncata Linné
Portlandia arctica (Gray)
Astarte montagui (Dillwyn)
Cyrtodaria kurriana Dunker
Clinocardium ciliatum (Fabricius)
Serripes groenlandicus (Bruguière)
Mytilus edulis Linné
Musculus discors (Linné)
Nucula belloti Adams
Yoldiella fraterna Verrill and Bush

Table IV-12. Distribution of Mollusca in the Cape Parry - Kent Peninsula region.

| | C. Parry-Clinton Pt. | | | | Clinton Pt. - Coppermine | | | | | | | | | | | | | | | Coppermine - Kent Peninsula | | | | | | | | | | | | | | |

Table IV-13: Summary of recent water temperatures, salinity and depth tolerated by some Late Quaternary molluscs of the postglacial sea.

Species	Depth (m)	Temperature (°C)	Salinity (ppt)
Hiatella arctica	<35 to 165	0 to -3	20 to 32
Macoma balthica	2 to 276	<10	4 to 35
M. calcarea	<76 to 276	0	>30
Mya truncata	<35 to 97	0 to -3	25 to 34
Portlandia arctica	10 to 400	< - 1	20 to 34
Mytilus edulis	intertidal	0 to >5	15 to 30
Clinocardium ciliatum	10 to 200	0 to -3	25 to 30
Astarte montagui	50 to 250	-1	33
Musculus discors	<50		>30
Yoldiella fraterna	<100 to <200		

30 ppt (Hillaire-Marcel, 1980). As noted within the present study, it is adapted to both sand and clay substrates.

Like the preceding species, *Mya truncata* also occurs within both shallow-water and deep-water marine environments. Wagner (1968) reported this species present at depths of 35 to 97 m in Hudson Bay, but was most abundant from waters 35 to 50 m deep. *Mya truncata* is a common bivalve of intertidal and upper sublittoral zones of the Canadian Arctic (Lubinsky, 1980), and is associated with depths of 5 to 75 m in Frobisher Bay with waters of 0°C and 32 ppt (Aitken, 1990). It presently occurs in the Darnley Bay area and north of Coppermine. Another species with a wide depth distribution is *Portlandia arctica*. Ockelman (1958) noted its presence at depths of 10 to 50 m near melt-water streams off the fronts of glaciers in Greenland, where cold, freshwater influx takes place, as well as in ice-proximal waters of 20 to 30 ppt in Frobisher Bay 5 to 40 m deep (Aitken, 1990). It has been found in waters 101 to 276 m deep from Hudson Bay, where bottom water temperatures did not exceed -1°C. It occurs today throughout the Arctic and is abundant at 10 to 400 m depth. This species was associated with clay sediments of the Champlain Sea (Rodrigues and Richard, 1983, 1985), representing a relatively deep offshore facies in which salinities ranged from 20 to 34 ppt. Because its environmental requirements are similar to those of *Macoma calcarea*, these two species occur in a number of samples from the Coppermine - Kent Peninsula region; its presence in several shallow-water Late Holocene localities (Table IV-12) suggests that it is also well-adapted to near-shore environments.

Mytilus edulis, associated with the shallow-water Assemblages C, E, 3 and 5 (Table IV-12), is largely restricted to the intertidal environment. Although it prefers rocky surfaces, it can survive on fine to coarse-grained sediments or other objects on the substrate. However, it is not as well adapted to brackish water as are other molluscs and prefers seasonally-warmer littoral waters. Its present distribution within the study area includes Dolphin and Union Strait (Dall, 1919), Coronation Gulf and Kent Peninsula.

The recent distribution of *Yoldiella fraterna* is not well known in the western and central Arctic, and it has only been reported near Kent Peninsula (Lubinsky, 1980); new fossil localities in the study area include Coronation Gulf and Bathurst Inlet (Table IV-11), where this species is associated with deep-water sediments of Assemblages D and 4. Scourse *et al.*, (1990) have reported its presence in Late Wisconsin glaciomarine sediments from the Celtic Sea at depths of 140 to 180 m. Recent specimens have been collected at a depth of up to 200 m on sediments of mud and rocks. Only one occurrence of *Musculus discors* has been noted (Table IV-11) in the present study east of Coppermine; it is associated with relatively deep-water sediments inferred to have been deposited in 60-70 m of water. The recent distribution of this species indicates that it is abundant and common in the Canadian Arctic, in waters less than 50 m deep, and throughout the study area (Lubinsky, 1980). Aitken (1990) reported its occurrence in Frobisher Bay in ice-distal

waters 5 to 75 m deep, with temperature and salinity of -1°C and 32 ppt. The fossil distribution of *Clinocardium ciliatum* ranges from Clifton Pt. to Queen Maud Gulf (Table IV-12), and is found in both deep and shallow-water sediments. Recent species are common in Dolphin and Union Strait, Coronation Gulf, Bathurst Inlet and throughout the Canadian Arctic at depths of 10 to 200 m on muddy gravelly sediments. *Cyrtodaria kurriana* has also been found in Pleistocene sediments along Amundsen Gulf in shallow and deep-water marine deposits; its recent distribution in the study area, however, is restricted to Dolphin and Union Strait further east (Table IV-12), suggesting that it may have been more widespread in the past, or that it is migrating easterly.

Nucula belloti is an abundant and common Arctic species in ice-proximal waters 30 to 560 m deep with a salinity of 32 ppt (Aitken, 1990). Although recent species have not been recorded between Darnley Bay and Kent Peninsula (Lubinsky, 1980), one site along Dolphin and Union Strait (Table IV-12) yielded fossils of *N. belloti* from shallow-water raised marine sediments. The presence of fossil forms and apparent absence of recent species could indicate significant changes in environmental conditions or more likely that recent molluscs have not yet been found. The recent distribution of *Serripes groenlandicus* in the study area is restricted to Bathurst Inlet. However, fossil distribution differs from recent occurrences, as only a single fossil locality has been noted by the author along Coronation Gulf in shallow-water sediments (Table IV-12). In Frobisher Bay, it has been found at a depth of 30 m in waters with a salinity of 32 ppt (Aitken, 1990).

DISCUSSION

The Cape Parry - Kent Peninsula study area falls within the recent faunal Province of Southwestern Canadian Archipelago (Lubinsky, 1980). The fauna consists of High Arctic species with some subarctic and boreal species, and has many similarities with the recorded mollusc fossils. Arctic species, associated with marine waters of low temperature and salinity and low seasonal fluctuations, include *Portlandica arctica, Yoldiella fraterna* and *Cyrtodaria kurriana.* Fossil occurrences for these species are generally related to relatively deep-water sediments. Arctic-boreal species have a greater tolerance to higher temperature and salinity, and include *Hiatella arctica, Mya truncata, Macoma calcarea, Clinocardium ciliatum, Serripes groenlandicus* and *Musculus discors.* In the Late Quaternary stratigraphic record, these fossils have been observed in shallow to deep-water sediments from Cape Parry to Kent Peninsula, reflecting glaciomarine to marine conditions. Subarctic species, often indicative of present-day warmer littoral waters, are represented by *Mytilus edulis, Macoma balthica* and *Astarte montagui.* These species are present in the shallow-water marine sediments of Assemblages B, D, 2 and 4 (Table IV-12).

The presence of marine bivalves in glaciomarine sediments in the study area and in close proximity to DeGeer moraines along the coast suggests that bivalve migration took place in the earliest phases of marine inundation in conjunction with ice retreat. At this time, *Portlandia arctica, Mya truncata, Hiatella arctica* and *Serripes groenlandicus* were already present in ice-marginal areas (Lubinsky, 1980). Patterns of ice retreat dictate that both micro and macrofauna migrated from west to east into newly-deglaciated extensions of the Franklin Sea. The distribution of shallow-water species attests to a similar pattern of migration for early Arctic and Subarctic species alike. Isostatic rebound and the resulting marine regression caused bivalve retreat from increasingly shallow-waters to the present-day coastal environment.

Recent polar waters of the Arctic consist of the surface and subsurface layers, characterized by ranges in fluctuation of temperature and salinity. The average surface layer is 50 to 70 m thick, with temperatures attaining 5°C and salinities that fluctuate seasonally, reaching as low as 4 ppt in summer (Lubinsky, 1980). In the more stable subsurface layer, temperature is below 0°C and salinity approximately 33-34 ppt. These two layers are important factors in the distribution of marine molluscs. The waters of the postglacial Franklin Sea may also have been density stratified with respect to salinity and temperature; waters with salinities of 30 to 34 ppt likely occupied the deeper parts of the sea and were overlain by waters with salinities of less than 30 ppt present at shallow depths. The geographic and stratigraphic distribution of distinct shallow and deep-water molluscs in the Cape Parry - Kent Peninsula region suggests that these two layers and their characteristic paleoenvironmental implications persisted throughout the marine regression. However, temperature and salinity stratification could have been more prevalent in shallow-waters where mixing of waters would be lessened by weak tidal action, as is the case today in the Coppermine region where the tidal range is approximately 0.3 m and less than 0.6 m in Bathurst Inlet.

The Arctic affinities of the fauna and the apparent absence of a more diversified bivalve assemblage can best be explained by a combination of controlling factors such as the relatively cold temperature of the water, an intermittent and/or insufficient supply in nutrients, the detrimental effects of persistent coastal and littoral sea ice, as well as considerable seasonal fluctuations in salinities.

SUMMARY AND CONCLUSIONS

The glaciomarine incursion of isostatically depressed coastal lowlands from Cape Parry to Kent Peninsula lead to the formation of the postglacial sea. This new inland extension of the Arctic Ocean experienced two fundamental faunal migrations: an initial phase of colonization following ice retreat from west to east, and a subsequent withdrawal phase evolving throughout

the period of marine regression. Figure IV-4 summarizes the distribution of assemblages by region and elevation for five major regions along the coast at 11 ka, 9 ka and 5 ka BP. Water depth associated with Assemblages A, C, E, 1, 3, 5 remains relatively consistent. For Assemblages B, D, 2, 4, water depth varies considerably more according to geographic location and time.

It has been shown that a rich and diverse marine fauna existed during the Late Wisconsin deglaciation phase. Furthermore, it has also been demonstrated that it is possible to interpret paleoenvironmental conditions on the basis of salinity and temperature. Micro and macrofaunal evidence is indicative of stable, near-normal marine conditions in the deeper parts of the sea, and brackish-water marginal marine environments in the upper part of the water mass resulting from the dilution of nearshore marine waters. These conditions have prevailed for the last 12 000 years to the present.

Modern environmental equivalents to conditions represented by Assemblages A and 1 can be found today as relatively shallow, brackish waters off the coasts of northern, southern and western Alaska and Siberia. Foraminiferal Assemblages B, D and ostracode Assemblages 2, 4 from some of the oldest marine sediments, record temperatures and salinities of approximately 0°C and 33-34 ppt respectively in deep-water environments. Modern-day faunal counterparts have been reported in relatively deep waters in Frobisher Bay and in coastal waters of Greenland, Alaska and Norway.

The shallower waters of the postglacial Franklin Sea, associated with Assemblages C, E, 3 and 5, represented a severe environment characterized by foraminiferal and ostracode faunas distinct from those associated with the deeper, more open-marine offshore environment. Only the most tolerant species of the shallow fauna were able to invade and successfully colonize this seasonally rigorous environment. Paleotemperatures may have attained 5-10°C in summer, whereas paleosalinities were likely in the range of 10 to 34 ppt, depending on climatic (seasonal) conditions. Low species diversity and the presence of agglutinated foraminifera are typical features of recent shallow northern-Alaskan waters. The distribution of bivalve mollusc species also reflects these two distinct shallow and deep-water environments throughout the study area and during the complete marine regression. The highly variable number of specimens and species of micro and macrofossils are closely related to changing depositional environments; glacial deposits are barren whereas transitional glaciomarine sediments possess an impoverished fauna. Postglacial marine deposits exhibit greatest abundance and diversity in offshore environments, but this decreases progressively in shallower, littoral sediments.

It is hoped that this paper, the first work of its kind for this part of the Arctic, will significantly aid future research, and serve as a basis for similar studies in the northern and eastern Arctic. The apparent discrepancies between certain recent and fossil mollusc occurrences require further investigations in order to identify potential trends in migration. Additional marine faunal studies in

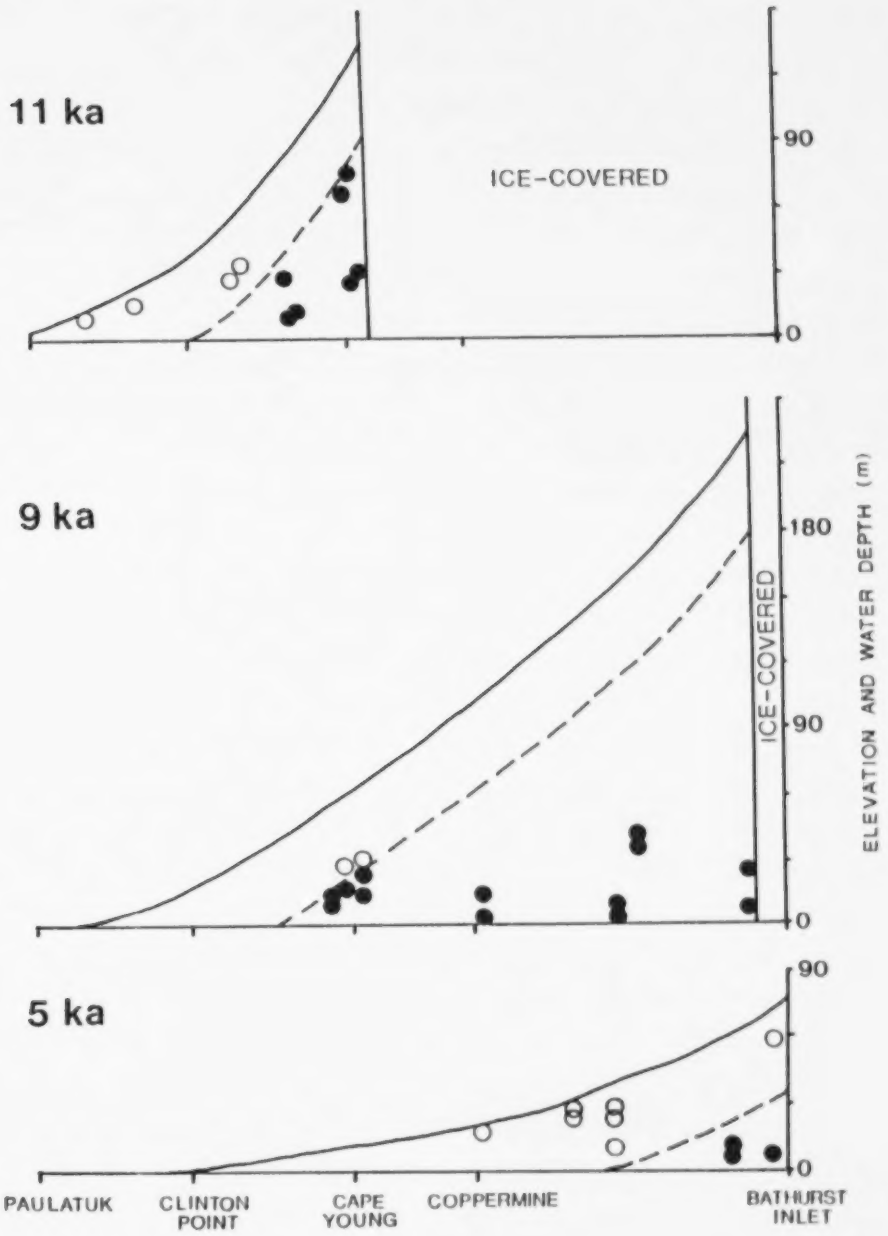

Figure IV-4: Distribution of assemblages and dated samples according to region and elevation for three time periods. Assemblages A, C, E, 1, 3, 5 (white dots) occur below sea level (solid line) and above dashed line (approximate depth 40 m). Assemblages B, D, 2, 4 (black dots) occur below dashed line (depth >40 m).

the Cape Parry to Kent Peninsula region may also help refine the temporal distribution of fauna which can be established from a greater number of radiocarbon dates throughout the marine regression.

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CHAPTER 5 - SUMMARY AND CONCLUSIONS

The objective of this study was to document and interpret the Late Quaternary coastal geology of the Parry Peninsula - Perry River area. This entailed an initial stratigraphic study in which sediments below marine limit were subdivided into seven facies. A regional lithostratigraphic review of 20 sections illustrated facies associations, continuity and geographic extent. The Late Wisconsin pattern of ice retreat for the Laurentide Ice Sheet was also presented. Increasing ice loads from the northwest to the southeast are reflected in seven emergence curves which portray local glacioisostatic responses during the Holocene. Throughout the marine regression, a relatively diverse micro and macrofauna populated various sedimentary environments. Their distribution in the fossil record suggests that paleoecological conditions in both deep and shallow Arctic waters, have changed little over the last 12 000 years.

The Late Wisconsin deglaciation history in the Parry Peninsula - Perry River area, Northwest Territories is reconstructed from a regional study of Quaternary stratigraphy and glacial landforms. The stratigraphic record in this isostatically-depressed coastal lowland area consists of a well defined succession of seven sedimentary facies: (A1) massive diamicton; (A2) stratified diamicton with sorted sediments; (B) small-scale horizontal and cross-stratified sand and gravel; (C) interlaminated sand, silt and clay; (D) massive silty clay; (E) thinly bedded sand, silt and clay; (F) poorly bedded to massive sand; (G1) large-scale cross-stratified sand and gravel; and (G2) large-scale horizontal and trough cross-stratified sand and gravel.

These facies result from a variety of rapidly changing depositional environments, beginning with the retreat of the Laurentide Ice Sheet from near its maximum limit through to postglacial marine emergence: (A1) till produced mainly by lodgement of glacial debris by active ice; (A2) glacial diamictons deposited by a combination of debris flows and iceberg rain-out modified by subglacial meltwater processes; (B) subaqueous outwash sediments issuing from subglacial meltwater conduits; (C) glaciomarine rhythmites deposited by sediment-laden underflows, interflows and overflows away from the ice margin; (D) postglacial marine fine-grained sediments resulting from suspension deposition; (E) sublittoral marine rhythmites influenced by tidal and fluvial processes; (F) marine littoral deposits representing the last phase of marine regression; and (G1, G2) glaciomarine and marine deltas constructed by glaciofluvial outwash and fluvial sediments during deglaciation and in postglacial times.

Ice retreat has left a relatively orderly and predictable sedimentary succession which is generally consistent over an area of 1 000 km. Two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (facies A, B, C, D) and a conformably overlying coarsening-upward regressive marine sequence (facies E, F, G). The distribution and lateral extent of each facies falls within a sequence in which

ice-proximal sediments (diamicton, outwash, rhythmites) shift landward during ice retreat, whereas marine sublittoral and littoral deposits (silty clay, sandy rhythmites, sand and gravel) shift seaward during the marine regression.

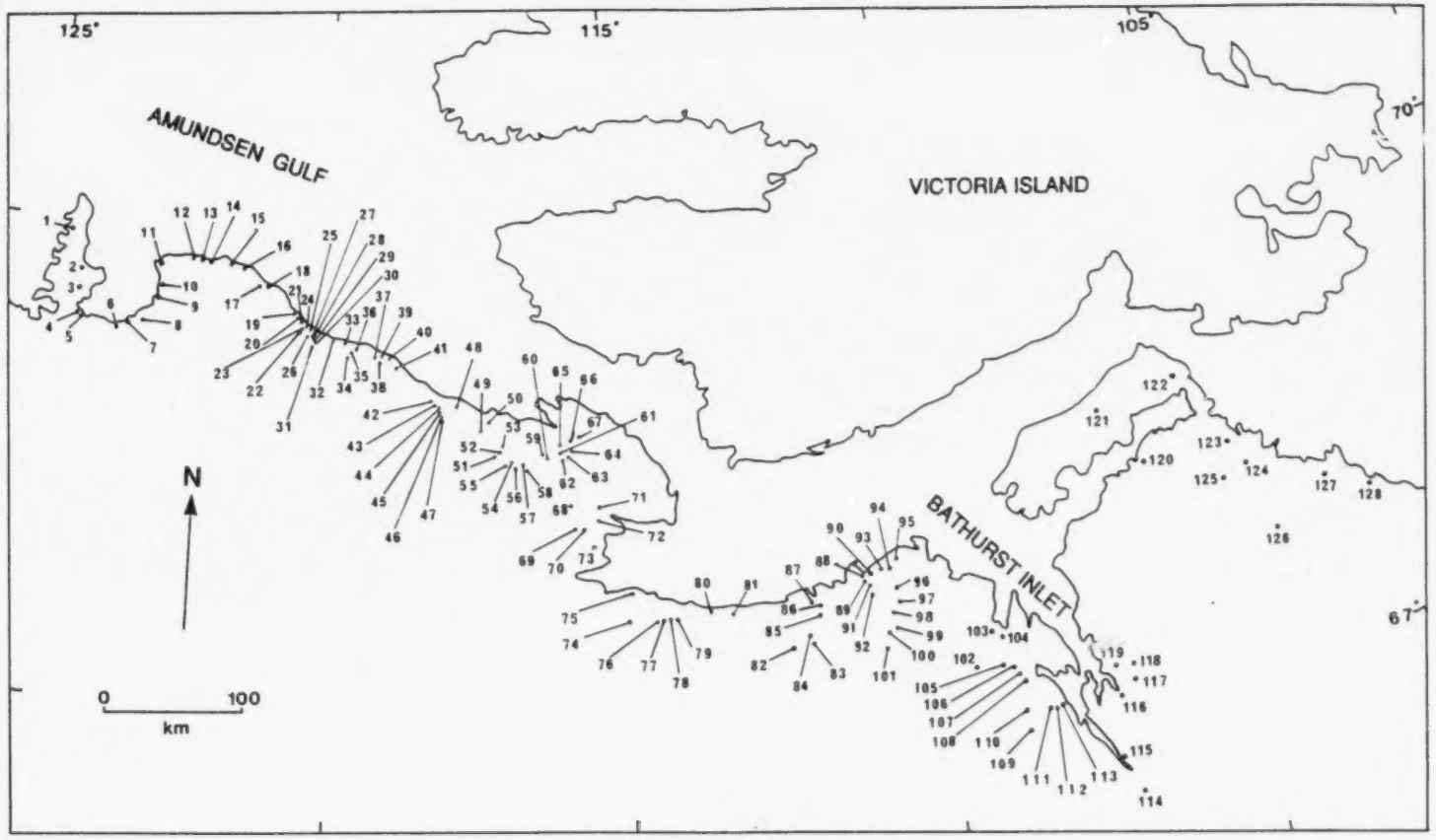
The Parry Peninsula - Bathurst Inlet region experienced rapid deglaciation in response to marine incursion of isostatically-depressed terrain and high sea level stands. Marine limits, frequently defined by ice-contact deltas, were formed at the time of deglaciation from approximately 12.5 ka BP to 9 ka BP from west to east respectively. Elevations range from approximately 10 m to 225 m a.s.l. and reflect local responses to ice loading of the crust. Seven relative sea level curves demonstrate that the mainland coast has shown initial rapid emergence and then progressively less emergence which has been replaced by submergence from Paulatuk to Bernard Harbour during the late Holocene. Regions to the east continue to experience emergence. Sea level curves have shown persistently higher rebound from west to east. The pattern and magnitude of observed postglacial sea level changes are in accord with theoretical predictions. In areas close to, but within the glacial limit, sea level initially falls during the early and middle Holocene, and then begins to rise due to the migration of the forebulge in late Holocene times. Submergence becomes progressively younger from west to east. However, further studies are required to determine detailed forebulge effects, as well as exact rates of ongoing emergence and submergence.

During the period of marine inundation, a rich and diverse marine fauna existed from which paleoecological conditions can be derived. Stable, near-normal marine conditions are associated with the deeper parts of the postglacial sea. Temperatures and salinities were in the range of 0° C and 33-34 ppt respectively. Modern-day faunal equivalents can be found off the coasts of Frobisher Bay, Alaska, Greenland and Norway. Relatively shallow waters are characterized by species different from those in open-marine offshore environments. Only the most tolerant foraminifera, ostracode and bivalve species were able to successfully colonize the severe sublittoral and littoral environments. Brackish-water marginal marine conditions resulted from dilution of nearshore marine waters. Paleotemperatures attained 5° to 10° C in summer, and paleosalinities ranged from 10 to 34 ppt. Postglacial marine deposits exhibit lowest abundance and diversity in nearshore environments, but this increases progressively in deeper-water sediments. Low species diversity is a typical feature of recent shallow northern Alaskan waters. Similar temperature and salinity conditions have prevailed for the last 12 000 years.

This study has contributed to a better understanding of Late Quaternary stages of deglaciation and postglacial history in the Parry Peninsula - Perry River area. Stratigraphic and sedimentological data were presented in order to describe the succession of sedimentary environments resulting primarily from the retreat of Laurentide ice. The study of such sequences, together with sea level data and paleoecological interpretations, provides more detailed

information that may serve to support and complete the reconstruction of the Late Quaternary history inferred by the mapping of surficial deposits.

Additional detailed stratigraphic and sedimentological investigations are required to further define the depositional environments presented in this dissertation. Of particular interest would be the region at the limit of the Late Wisconsin Laurentide Ice Sheet (west of Franklin Bay and on Banks Island), and immediately beyond. Existing interglacial deposits could then be related to sediments of the last glaciation within the limits of glaciation. A greater number of radiocarbon dates are also required to complete the temporal framework of deglaciation. More accurate patterns of postglacial crustal recovery and ice-loading events may be revealed based on a greater number of well-controlled sea level curves from specific sites along the coastline and on adjacent islands. Furthermore, micro and macrofossil studies can be expanded to include detailed site investigations beyond, at and within the glacial limits. These can include potential studies in trends in migration and species diversity over time.



Appendix II-1: Location of stratigraphic sections.

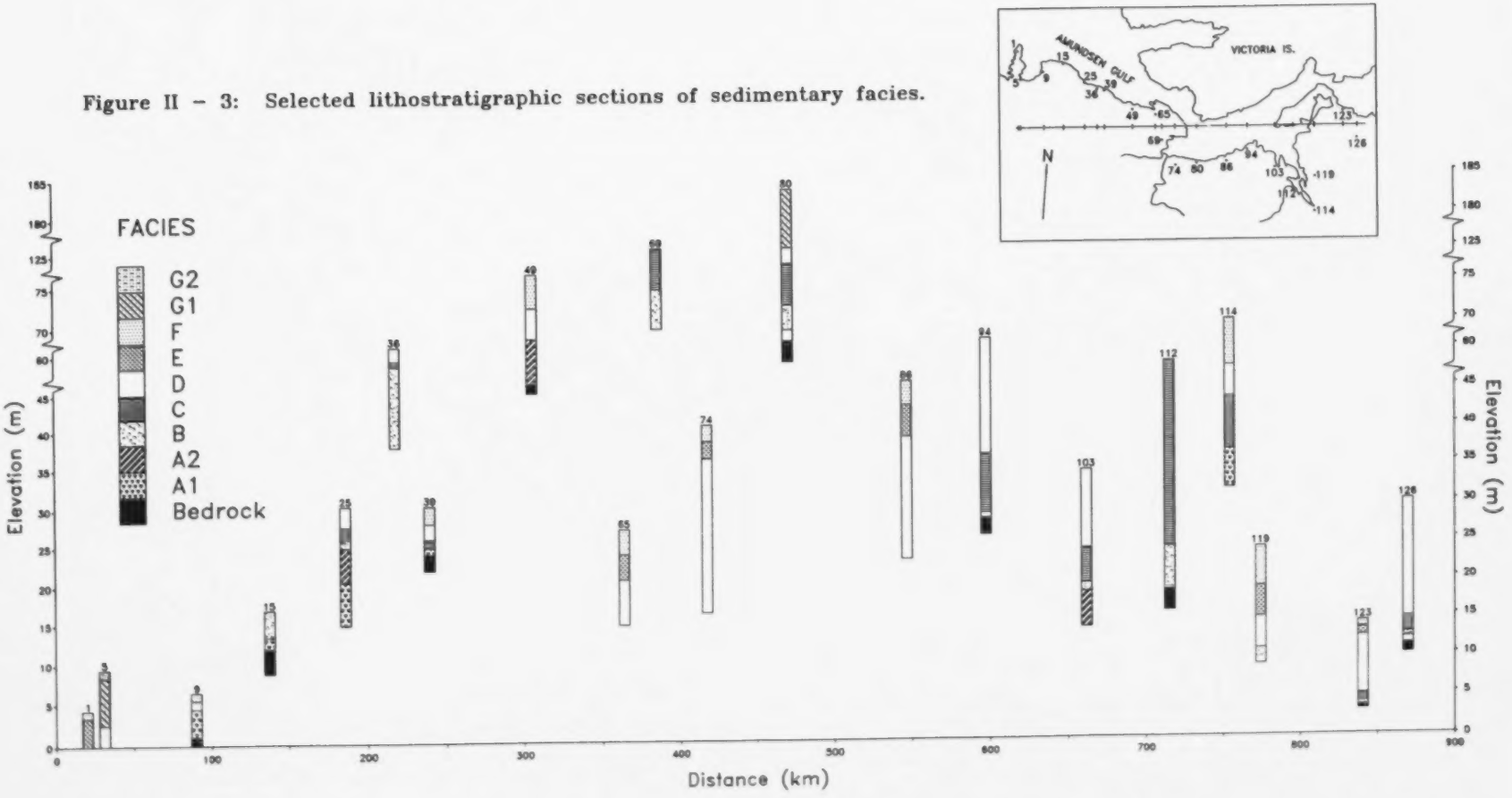



Figure II – 3: Selected lithostratigraphic sections of sedimentary facies.